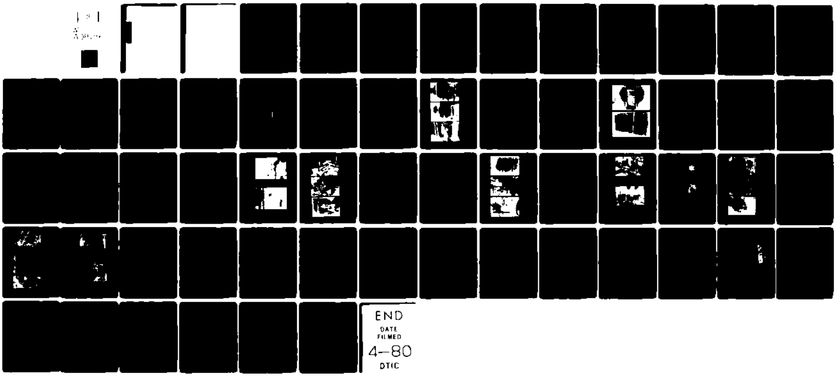
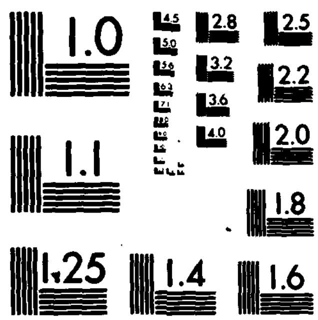
AD-A082 160 COAST GUARD RESEARCH AND DEVELOPMENT CENTER GROTON CT F/G 13/12
CHIEF PETTY OFFICER (CPO) BERTHING COMPARTMENT BURNOUT TESTS.(U)
MAR 80 C D WOLVERTON
UNCLASSIFIED CGR/DC-16/79 USCG-D-78-79 NL





MICROCOPY RESOLUTION TEST CHART

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
18 USCG 19 D-78-79 6 Chief Petty Officer		

4. Title and Subtitle	5. Report Date
CPO BERTHING COMPARTMENT BURNOUT TESTS	11 MARCH 1980
	6. Performing Organization Code
7. Author(s) 10 Charles D. Wolverton, Jr 12 63	8. Performing Organization Report No. 14 CG RDC-16/79
9. Performing Organization Name and Address United States Coast Guard Research and Development Center Avery Point Groton, CT 06340	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address Department of Transportation United States Coast Guard Office of Research and Development Washington, DC 20593	13. Type of Report and Period Covered 9 FINAL Rept.
	14. Sponsoring Agency Code

15. Supplementary Notes

Performed at the U.S. Coast Guard Fire and Safety Test Detachment under the technical supervision of the U.S. Coast Guard Research and Development Center, Avery Point, Groton, Connecticut 06340.

16. Abstract This series of six tests evaluated performance of three types of lightweight non-structural bulkhead panels when subjected to berthing compartment fire conditions. The tests were conducted in full-scale compartments constructed aboard the test vessel ALBERT E. WATTS at the U.S. Coast Guard Fire and Safety Test Detachment, Mobile, Alabama. Each test compartment simulated a typical Coast Guard cutter 2-man chief petty officer berthing compartment arrangement, including standard shipboard furniture (bunks, clothing lockers, bookrack and chair). A realistic fuel load was provided, including clothing, publications, and standard issue mattresses and bedding. Fuel load arrangement, test compartment ventilation, method of ignition and test duration (60 minutes) were similar in all cases. Maximum recorded temperatures inside the test compartments ranged between 818° C and 965° C.

The tests showed that all three panel designs were capable of containing a fire for 30 minutes or more. The panel cores charred extensively, resulting in widespread separation from the facing sheets, but there were no burnthroughs or significant breakdowns of panel integrity. All types of panels successfully supported a fully-loaded bulkhead mounted bookrack weighing over 100 pounds. It was also demonstrated that proper support of the bulkhead panels in their joiner system is a vital factor in insuring that compartment bulkheads retain their integrity during a serious fire. Bulkhead breaches that occurred during the tests appeared to be the result of inadequate joiner system assembly rather than failure of the panels themselves.

17. Key Words	18. Distribution Statement
Fire tests Berthing compartment fires Lightweight bulkhead panels Shipboard joinerwork bulkheads	Document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED		

Form DOT F 1700.7 (8-72) Reproduction of form and completed page is authorized

1 401730

METRIC CONVERSION FACTORS

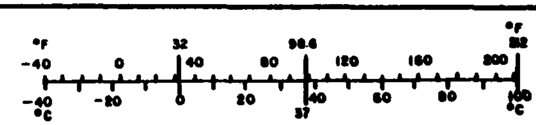
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



ACKNOWLEDGEMENTS

The United States Coast Guard appreciates the assistance of Advanced Structures Corporation, CIBA-Geigv, E.I. DuPont de Nemours & Company, Incorporated, and Hexcel Structural Products in providing materials and information which aided in the successful accomplishment of this test series. The tests described in this report are part of a continuing fire research program planned and conducted by the United States Coast Guard with the participation and cooperation of private industry.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1.0 INTRODUCTION

Saving weight has become an important objective in the design of Coast Guard cutters. As increasing amounts of navigation and communication equipment are installed high in a ship, other topside weights must be controlled in order to maintain adequate vessel stability. Accommodation space joiner bulkhead paneling is an area where significant weight economies may be possible through the use of new construction materials. Joiner bulkheads aboard existing cutters are constructed of Marinite panels, which consist of one-piece boards of calcium silicate, inert fillers and a reinforcing agent. This material satisfies current fire performance requirements, and it will probably continue in use where its weight (approximately 100 pounds per standard 4-foot by 8-foot panel) is not considered to be a problem. Coast Guard Headquarters Naval Engineering Division (G-ENE) is investigating lighter-weight alternatives for possible use in the construction of new 270-foot medium endurance cutters, as well as for replacement paneling in existing ships undergoing rehabilitation.

This report describes tests that were performed at the U.S. Coast Guard Fire and Safety Test Detachment (F&STD), Mobile, Alabama, to determine the performance of three candidate types of bulkhead panels when subjected to a fire in a typical Chief Petty Officer berthing compartment arrangement. The panel designs differed primarily in the type of integral facing sheets, as described in Table 1. Each of the three designs had a nonmetallic structural honeycomb core of Nomex high temperature resistant nylon material. The honeycomb core cells were filled with phenolic foam. Other panel characteristics are given in Table 1.

TABLE 1

BULKHEAD PANEL DESCRIPTION

INTEGRAL FACING TYPE	CORE MATERIAL	CORE FILLER MATERIAL	NOMINAL PANEL DIMENSIONS	WEIGHT PER PANEL
Nonmetal (Phenolic resin fiberglass)	Nomex aramid honeycomb (1/4" cell size)	Phenolic foam	4'x8'x5/8"	23 pounds
Galvanized Steel (0.018" steel thickness)	Nomex aramid honeycomb (1/4" cell size)	Phenolic foam	4'x8'x5/8"	58 pounds (including galvanized coating
Painted* Steel (0.023" steel thickness)	Nomex aramid honeycomb (1/4" cell size)	Phenolic foam	4'x8'x5/8"	79 pounds (including paint)

* One coat epoxy primer, Formula 150, MIL-P-24441 (2.0 to 2.5 mils thick) followed by two coats chlorinated alkyd base, Formula 124, MIL-E-17970 (each coat 2 mils thick).

2.0 TEST OBJECTIVES

This test series was designed to determine the performance of three candidate panel designs when subjected to a fire that could occur in a typical berthing compartment. Performance criteria established by Commandant (G-ENE) were as follows:

1. The bulkhead panels should contain the fire for at least 15 minutes.
2. The temperature 3 inches away from the exterior (unexposed) panel surfaces should not exceed 350°F.

These criteria were based on the following considerations:

a. Any significant fire in a berthing compartment would not be expected to burn for more than 15 minutes before a damage control party would be on the scene and extinguishment efforts would be begun. At that point, the fire should still be contained within the compartment of origin, so that firefighting efforts could be effectively concentrated and the fire quickly extinguished without further damage to adjacent areas.

b. Thermal energy will be transmitted through all boundaries of the compartment containing the fire. The heat absorbed by objects in surrounding compartments could cause them to ignite and spread the fire even if the boundaries between compartments remain intact. If temperatures 3 inches away from a burning compartment's exterior bulkhead surfaces do not exceed 350°F, the chances of fire spread due to transmitted heat will be small. The material most likely to ignite at the lowest temperature is bedding on a bunk located next to a heated bulkhead. The self-ignition temperature for woolen blankets and cotton sheets is 400°F or more.

A secondary objective for the tests was to determine the time-temperature characteristics at various locations within a test compartment during a fire. This information can be compared with results of previous similar tests and with standard laboratory fire test procedures such as ASTM E119, Standard Methods of Fire Tests of Building Construction and Materials, to determine the amount of correlation between the standard test conditions and actual fire conditions.

3.0 BACKGROUND

Standard E119 defines test methods that have been developed to allow comparison of many types of structural materials and assemblies for buildings. Fire resistance of a partition, bearing wall, girder, column, or other structural element is determined by incorporating it into one wall of a test furnace. During a test, the furnace internal temperature is controlled to follow a specified time-temperature curve by varying the fuel flow to burners inside the furnace. The E119 time-temperature curve (part of which is shown in Figure 18) initially rises rapidly, reaching 1000°F (538°C) at 5 minutes into the test. Beyond this point, the temperature is increased more slowly, so that at the end of one hour, the furnace temperature is 1700°F (927°C). The maximum test temperature, 2300°F (1260°C), is reached at 8 hours and held constant thereafter. Material performance is expressed as the period of resistance to the standard test exposure that elapses before the first critical point in behavior (e.g., breaching of a partition panel) occurs.

Time-temperature relationships observed in this testing were compared with E119 standard conditions (see Section 7.5). Comparison with results reported in previous testing was not an objective for this test series, however.

Most room fire tests reported in the literature have simulated residential or commercial building construction features and fuel loadings. Some significant fire reseach projects involving shipboard accommodation spaces are:

SS NANTASKET stateroom fire tests
(reported in "Fire Control for Passenger Vessels," Transactions of the Society of Naval Architects and Marine Engineers, Vol. 45, 1937)

USCG-GIBBS & COX stateroom fire tests
(reported in "Stateroom Fire Test," Transactions of the Society of Naval Architects and Marine Engineers, Vol. 58, 1950)

British Ministry of Transport cabin burnout tests
(reported in "Fire Protection in Passenger Ships," Quarterly Transactions of the Institution of Naval Architects, Vol. 95, No. 1, January 1953)

USCG merchant ship crew's lounge compartment burnout test series, Nos. 1-6
(to be published)

USCG joiner panel tests
(report on Coast Guard Ship Compartment Fire Tests, Naval Weapons Center Document Register Number 3271-040-77, dated 4 March 1977)

NBS berthing compartment full-scale fire tests
(report on Naval Shipboard Fire Risk Criteria - Berthing Compartment Fire Study and Fire Performance Guidelines, National Bureau of Standards report NBSIR 76-1052, September 1976)

In the published marine fire research literature, no other test series are known in which the significant aspects (i.e., full-scale multiple small shipboard berthing compartments, realistic furnishings, fuel load and ventilation, and highly instrumented individual bulkhead panels) were the same as in the tests reported here. Accordingly, no discussion of previous tests nor attempts at correlating their results have been included in this report.

It is felt that the conditions established for this test series subjected the test panels to a fire exposure that is realistic in view of their intended use aboard Coast Guard cutters, regardless of how this exposure might compare with conditions that occurred in previous tests.

4.0 METHOD OF TESTING

4.1 Control of Test Conditions

To obtain meaningful results, test conditions should simulate a "worst-case" situation, but without being unreasonably severe. Also, conditions should be the same for all tests. If the test conditions are made too severe, they could cause rejection of panel designs that would be entirely satisfactory in the vast majority of real fires. On the other hand, if tests are not demanding enough, panels giving inadequate fire protection might be selected for shipboard use. Less severe test conditions would also tend to mask any performance differences between panel types.

Two basic approaches are possible in fire testing. In the first, items are exposed to a fire whose time-temperature or ignition characteristics are closely controlled so as to follow a predetermined set of values. ASTM E119 is an example of this type of test. In the second approach, a realistic setting is created in which a fire is ignited and allowed to progress without hindrance. Rather than attempt to predict (and recreate) the variation of temperature with time and location within a compartment of this type, it was decided to simulate the fuel loading and arrangement of an actual CPO berthing compartment and allow the test fire to burn normally.

Ideally, the time-temperature histories of all fires in a given test series should be identical, so that all test items are stressed equally. Exact duplication of pre-fire conditions might theoretically result in identical time-temperature curves, but there will always be variations caused by uncontrollable factors in a compartment burnout test series such as this. For instance, the timing and extent of ceiling panel collapse, warpage of bulkhead panels within the tracking system, and heat absorption characteristics of the different types of bulkhead panels cannot be controlled without decreasing the realism of the test.

Maintaining complete control of other variables affecting fire behavior would increase testing costs enormously, while achieving benefits of doubtful importance. As one example, ventilation air was supplied to the test compartments continuously during the tests. To ensure complete repeatability of ventilation air properties, control of temperature and moisture content of the air would have been necessary for a considerable time before, as well as during, the tests. The expense of installing an air conditioning system capable of continuous and accurate control of air properties was not considered justified for this test series.

4.2 Test Compartments

To simulate Coast Guard cutter Chief Petty Officer (CPO) berthing spaces, standard-size (8-foot by 4-foot) bulkhead panels were assembled to form individual test compartments. The compartments were constructed on the bridge deck of the tank vessel ALBERT E. WATTS at F&STD. As shown in Figure 1, one test compartment was located at each corner of the deckhouse. On each side of the ship, the space between the forward and aft test compartment was enclosed to form an instrumentation compartment.

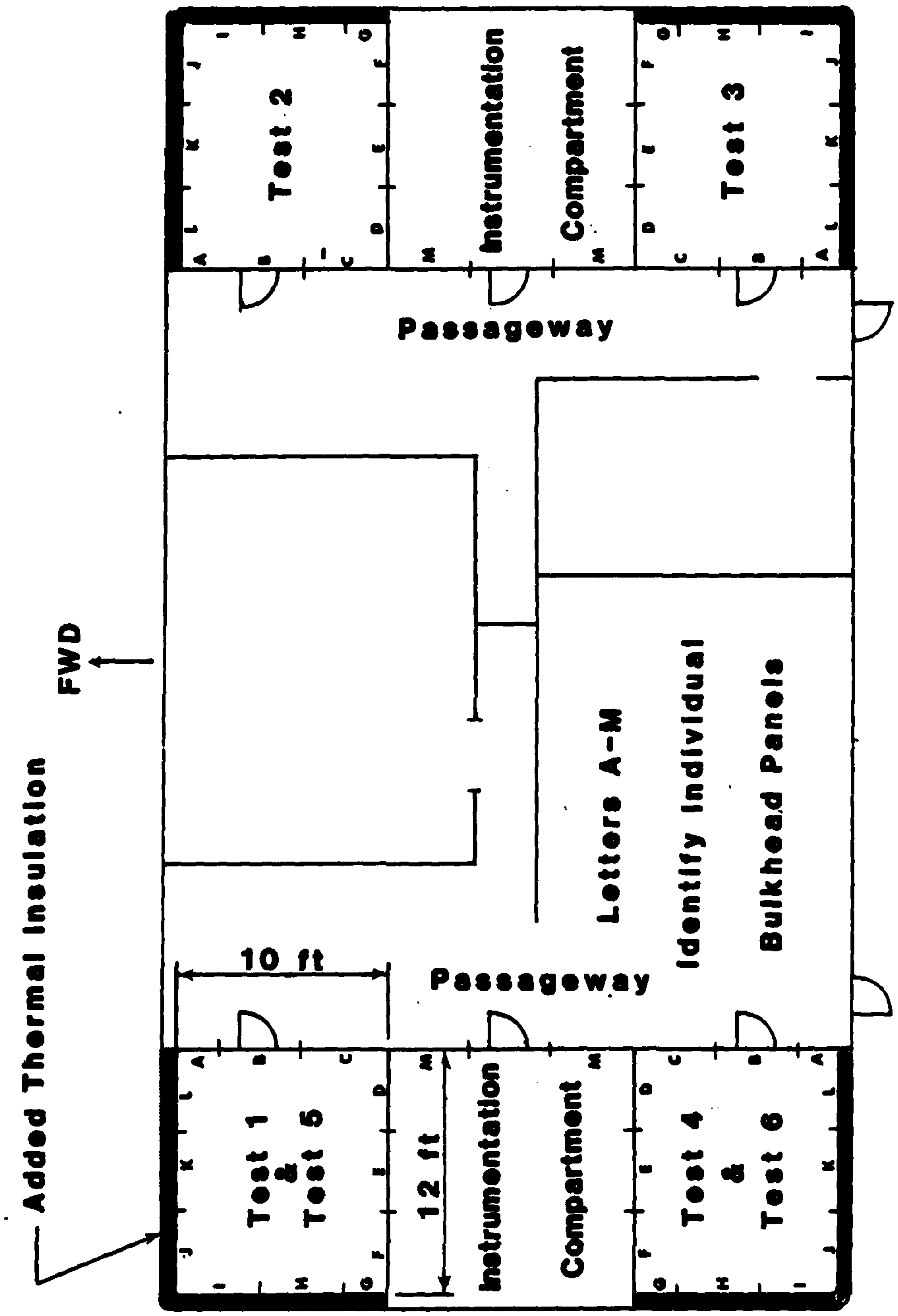


FIGURE 1

TEST COMPARTMENT LOCATION ON BRIDGE DECK OF T/V ALBERT E. WATTS

Each test compartment was constructed using only one type of panel. Each of the different types of panels was tested twice, for a total of six tests. Testing was divided into two phases. Tests 1 through 4 were conducted during the first phase, after which two additional test compartments were constructed on the port side of the bridge deck. Tests 5 and 6 were then conducted in the same locations as Tests 1 and 4, respectively. Within each compartment, individual bulkhead panels were identified by the letters A through M, as shown in Figure 1. Individual joiner system components are identified in this report by the letters of the bulkhead panels they support; e.g., H-post J/K or corner post C/D/M.

The compartments were tested in the order given in Table 2.

TABLE 2

ORDER OF TESTS

Test Number	Panel Type	Compartment Location	Test Date	Air Temperature/ Relative Humidity
1	Nonmetal-faced	Port-forward	9 Mar 79	60°F/55%
2	Galvanized steel-faced	Starboard-forward	13 Mar 79	66°F/70%
3	Painted steel-faced	Starboard-aft	16 Mar 79	65°F/39%
4	Nonmetal-faced	Port-aft	20 Mar 79	72°F/76%
5	Painted steel-faced	Port-forward	17 Apr 79	80°F/44%
6	Galvanized steel-faced	Port-aft	19 Apr 79	80°F/56%

Each test compartment measured 10 feet by 12 feet, the size of a typical two-man CPO berthing space. A 26-inch by 74-inch doorway was located in one of the 10-foot sides. Since the compartments were built in the corners of the deckhouse, each had two adjacent bulkheads facing the ship's weather bulkheads. Glass fiber insulation with a bulk density of one pound per cubic foot and conforming to specification MIL-I-22023 was installed in the space between the test compartment and the ship's weather bulkheads. Insulation thickness was 2 inches on plating and 1 inch around stiffeners. Port light recesses in the weather bulkheads in the area of the test compartments were blanked off with steel plates.

The bulkhead panels were supported by a conventional steel joiner system, modified to accommodate the 5/8-inch test panel thickness. H-posts designed for standard 7/8-inch panel thickness were modified by bending the outer 1/4-inch of the flanges on the female section inward 90 degrees so as to reduce the distance between mating flanges to 5/8-inch. H-post configuration

is shown in Figure 2. The female H-post sections were installed on the inside of the test compartments in all cases.

Upper and lower edges of the bulkhead panels were retained by 16-gage steel Z-bars inside the test compartments. The upper Z-bars were bolted to a curtain plate which was in turn welded to the underside of the deck above. The lower Z-bars were bolted to a coaming plate welded to the deck. A false overhead consisting of 2-foot by 4-foot fiberglass ceiling panels was suspended 81 inches above the deck in each test compartment. The false overhead was supported by an aluminum suspended grid system. No insulation was installed above the false overhead. A ventilation terminal with an 11 inch square throat area was installed flush with the false overhead in the middle of each test compartment. For use in extinguishing the fire at the end of the test, a sprinkler head was installed near the ventilation terminal.

4.3 Furniture

Test compartment furniture consisted of an aluminum double bunk unit, three aluminum lockers, a aluminum bulkhead-mounted bookrack, a steel straight-back chair and a steel wastepaper basket. All furniture items were of the same designs as used aboard Coast Guard cutters, and are described in Appendix A. Two furniture arrangements were used. In Tests 1, 2 and 3, the bunk units were placed next to the instrumentation compartment bulkhead, while in Tests 4, 5 and 6, the lockers were next to that bulkhead. Figure 3 shows the two furniture arrangements.

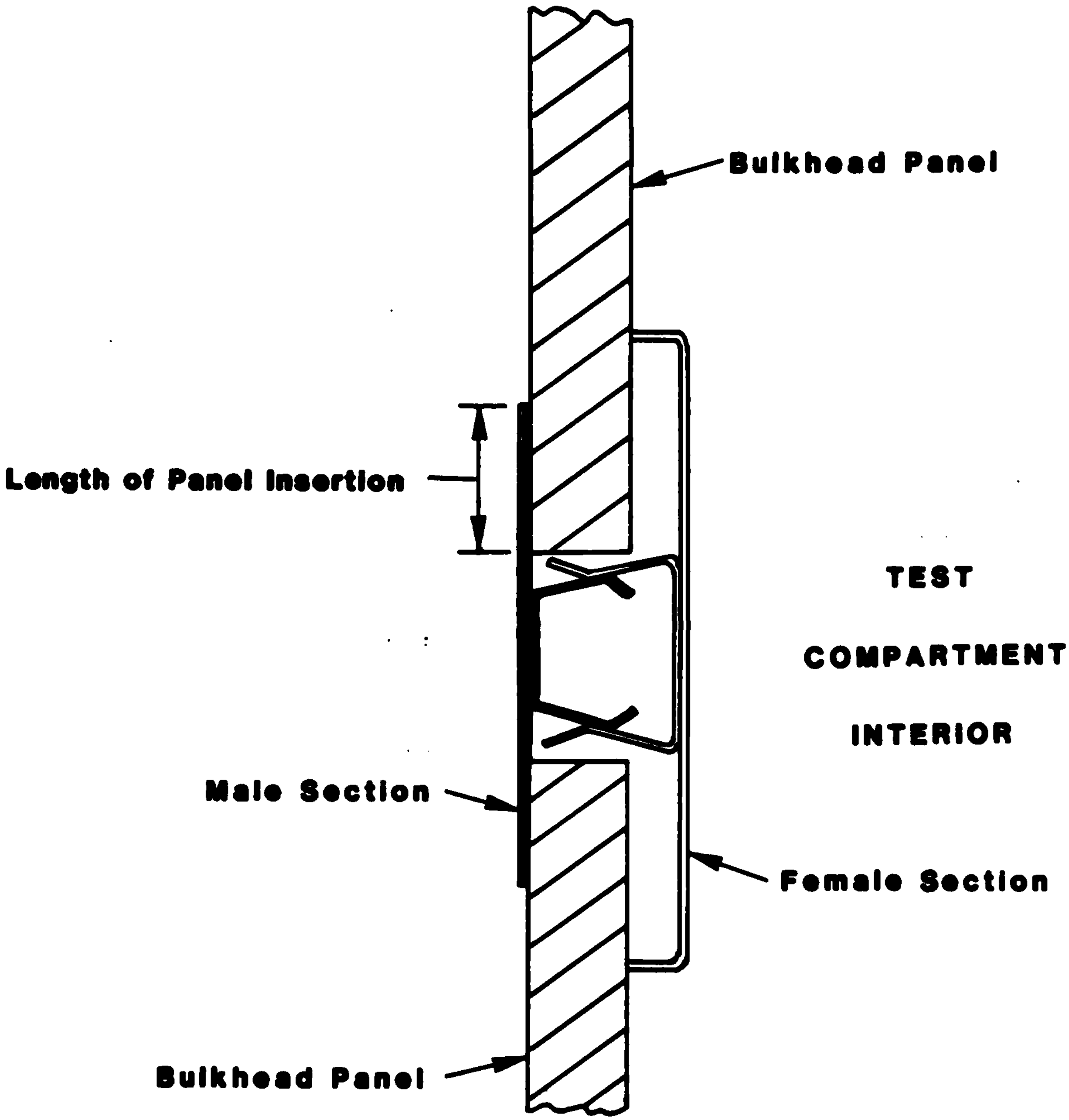
4.4 Combustible Items

Combustible items inside the test compartment were intended to simulate the fuel loading that would be present in a typical 2-man CPO berthing compartment. A neoprene foam mattress, a feather pillow, and a full set of bedding was provided in each bunk. Bedding items have the same Federal Stock Numbers as specified in Coast Guard cutter allowance lists. See Appendix B for a detailed description of bedding items.

Three clothing lockers were installed in each test compartment, providing a total of 6 feet of clothing storage rack length per compartment. Fifty pounds of assorted clothing was hung in each locker. An additional ten pounds was placed in drawers at the bottom of the bunk unit and distributed on the deck to promote spread of fire from the point of origin to the lockers and bookrack. Because of the large quantity needed, used clothing was obtained locally for the tests. Most of it appeared to be polyester blended fabrics.

A total of 140 pounds of publications in the form of magazines, paperback books, and newspapers was placed in each test compartment. Of this, 115 pounds of magazines were located in and on the bulkhead-mounted bookrack, along with 12 standard plastic covered 3-ring binders. Twenty pounds of paperback books were placed in the bookshelves of both bunks. The remaining five pounds of newspapers were distributed in the bunks and on the deck, to help spread the fire throughout the test compartment.

In an actual CPO berthing compartment, a writing desk would probably be provided. To simulate the contents of a desk, as well as the miscellaneous



(PLAN SECTION VIEW)

FIGURE 2

PLAN SECTION, H-POST CONFIGURATION

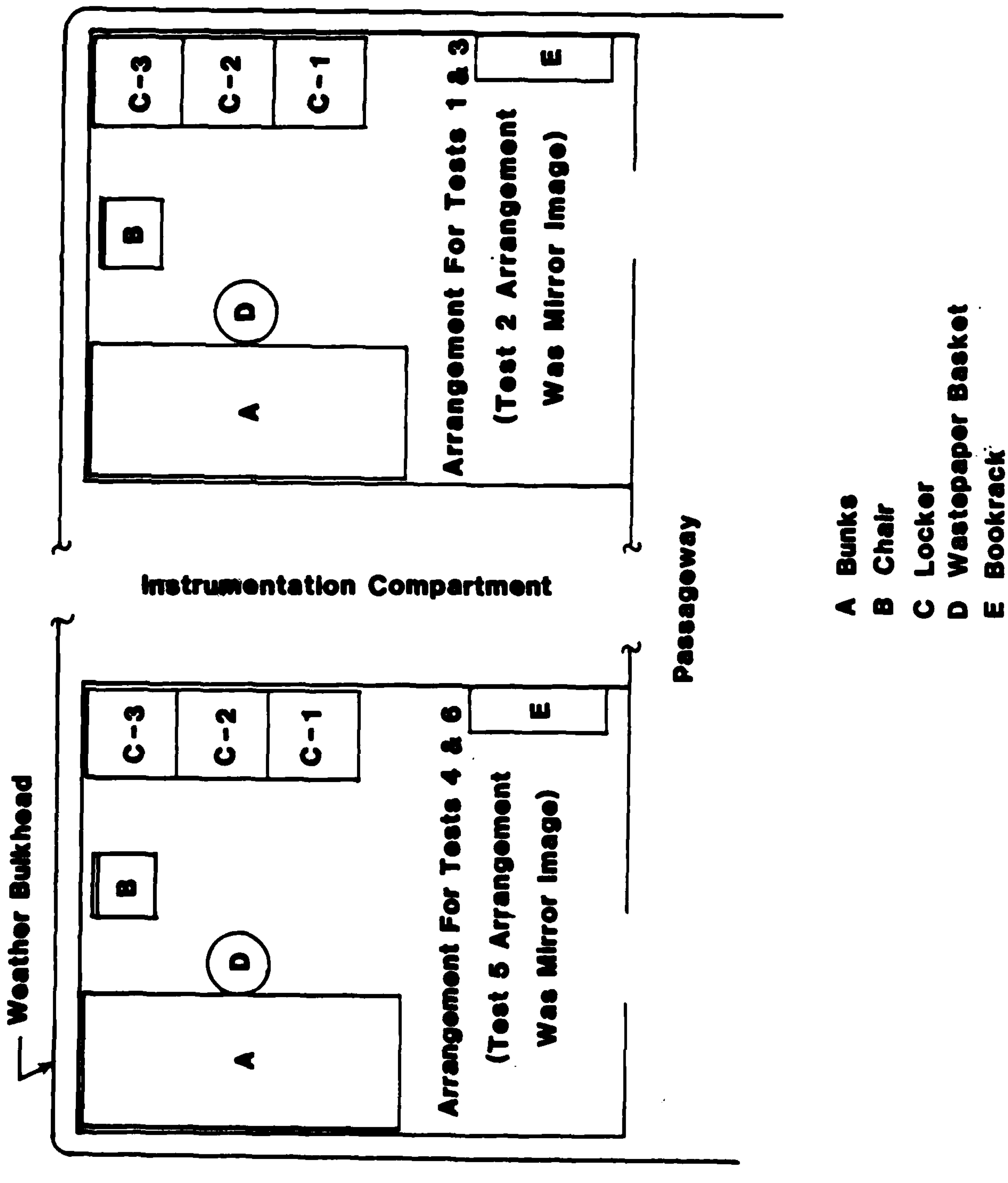


FIGURE 3

TEST COMPARTMENT ARRANGEMENTS

combustible personal items that would normally be present inside the compartment, 40 pounds of 4-inch by 5/8-inch white pine boards was added to the test fuel loading. The wood was broken into pieces about 2 feet long and half was placed on top of the bedding in each bunk.

Other small amounts of fuel included chair upholstery, plastic facing on the fiberglass ceiling panels, paint on the metal furniture, and wood and plastic clothes hangers. No floor covering was present, since none is included in CPO berthing space allowance lists. These combustible items are listed in Table 3.

TABLE 3

COMBUSTIBLE ITEMS

Item	Pounds Per Compartment
Neoprene mattresses	48
Feather pillows	5
Cotton and polyester bedding and towels	18
Wool blankets	7
Clothing	160
Publications	140
Wood	40
Ignition source and misc.	20
Total per compartment:	438

The resulting fuel loading was 3.7 pounds per square foot of floor area.

4.5 Ignition Source

The point of origin for each test fire was a steel wastepaper basket placed on the deck against the middle of the lower bunk. Five empty plasticized cardboard quart-size milk cartons and a small amount of naphtha were placed in the basket as the ignition source. The lower bunk bedding was arranged so as to trail into the basket to help spread the fire to the bunks. Bedding was also draped over the side of the upper bunk directly over the wastepaper basket. Individual pieces of clothing were laid on the deck and chair with their ends inserted into the basket. Typical appearance of the compartments prior to ignition is shown in Figure 4.

4.6 Ventilation

Throughout each test, ventilating air was supplied via an overhead terminal located approximately in the center of the test compartment. A ventilation air flow of 400 cubic feet per minute was selected as representative of the rate normally supplied to two-man berthing compartments. The test compartment door was removed, and all weather ports and interior doors on the bridge deck were closed.

(a) Bunks

(b) Lockers

(c) Bookrack

FIGURE 4

TYPICAL TEST COMPARTMENT INTERIOR ARRANGEMENTS BEFORE FIRE

4.7 Duration of Tests

Each test fire was allowed to burn for at least 60 minutes from the time of ignition; most temperatures had dropped significantly from their peak values by this time. The test fires were extinguished by using a combination of the overhead sprinkler and hand hose lines.

5.0 INSTRUMENTATION

Data obtained in this test series included temperatures, gas concentrations, heat flux and airflow into and out of the test compartment. See Appendix C for a complete list of the 99 data channels used. Temperatures were measured by thermocouples at 80 locations, including compartment atmosphere, internal and external bulkhead panel surfaces, the zone three inches away from the external bulkhead surfaces, and the clothing lockers. All thermocouples were type K. Thermocouples located inside the test compartment were 20 gage, Inconel sheathed. Thermocouples located outside the compartment were the exposed junction type with fiberglass insulated wire.

To indicate areas where 350°F was exceeded at 3 inches away from the bulkhead panel exterior surfaces, "Tempilabel" temperature monitors were used. Each monitor had four temperature-sensitive areas which changed color irreversibly upon reaching 330°F, 340°F, 350°F and 360°F, respectively. The monitors were mounted in a grid pattern on frames located outside the test compartment facing ther passageway and instrumentation compartment bulkheads. Figure 5 shows the exterior of typical test compartment bulkheads with the temperature monitor labels in place on their support frames. The labels were attached to small sections of asbestos shingles, which appear as small white rectangles in the figure. The labels were on the side of the shingle sections toward the bulkhead.

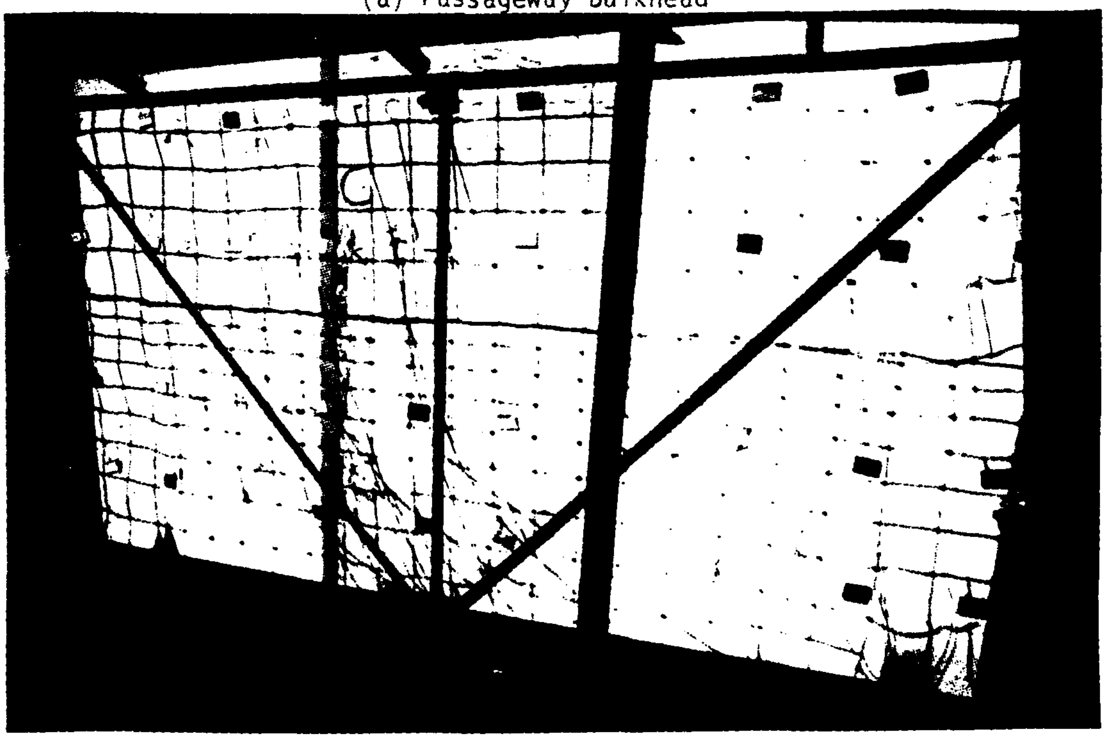
Concentrations of oxygen, carbon monoxide and carbon dioxide were measured at two locations inside the test compartment and one location in the doorway. Measurement of heat flux through the passageway bulkhead, the deck, and the false ceiling were obtained from two radiometers and four calorimeters. Airflow rate and direction was measured with bi-directional air flow probes. One was located in the ventilation supply duct and three were to have been installed in the compartment doorway. The lowest doorway probe was deleted before the first test because airflow in its vicinity would have been badly distorted by presence of one of the large video camera boxes which almost completely blocked the lower portion of the doorway.

Each test was videotaped using two cameras. One camera was positioned at the doorway to provide a view inside the test compartment, and the other was located in the passageway to observe the exterior bulkhead surfaces adjacent to the doorway. (See Figure 6.)

A still camera with infrared film was located in the instrumentation compartment, with a viewing angle that included the entire test compartment's athwartship bulkhead, as shown in Figure 6. The camera was fitted with a motorized 250-frame film magazine which allowed one exposure to be made every 15 seconds during the tests. This arrangement was intended to provide a means of determining the time and location at which any burn-throughs or major bulkhead failures occurred during the tests. An ultraviolet detector was also located in the instrumentation compartment to provide immediate indication of any significant breaches in the bulkhead allowing flames to pass through.

With a few minor exceptions, instrumentation positions relative to compartment furniture remained the same for all tests. Thermocouple locations on exterior bulkhead surfaces and on the frames 3 inches aways from the bulkheads were also maintained with few changes during the tests. Figure 7 shows the

(a) Passageway Bulkhead



(b) Instrumentation Compartment Bulkhead

FIGURE 5

TYPICAL TEST COMPARTMENT EXTERIOR

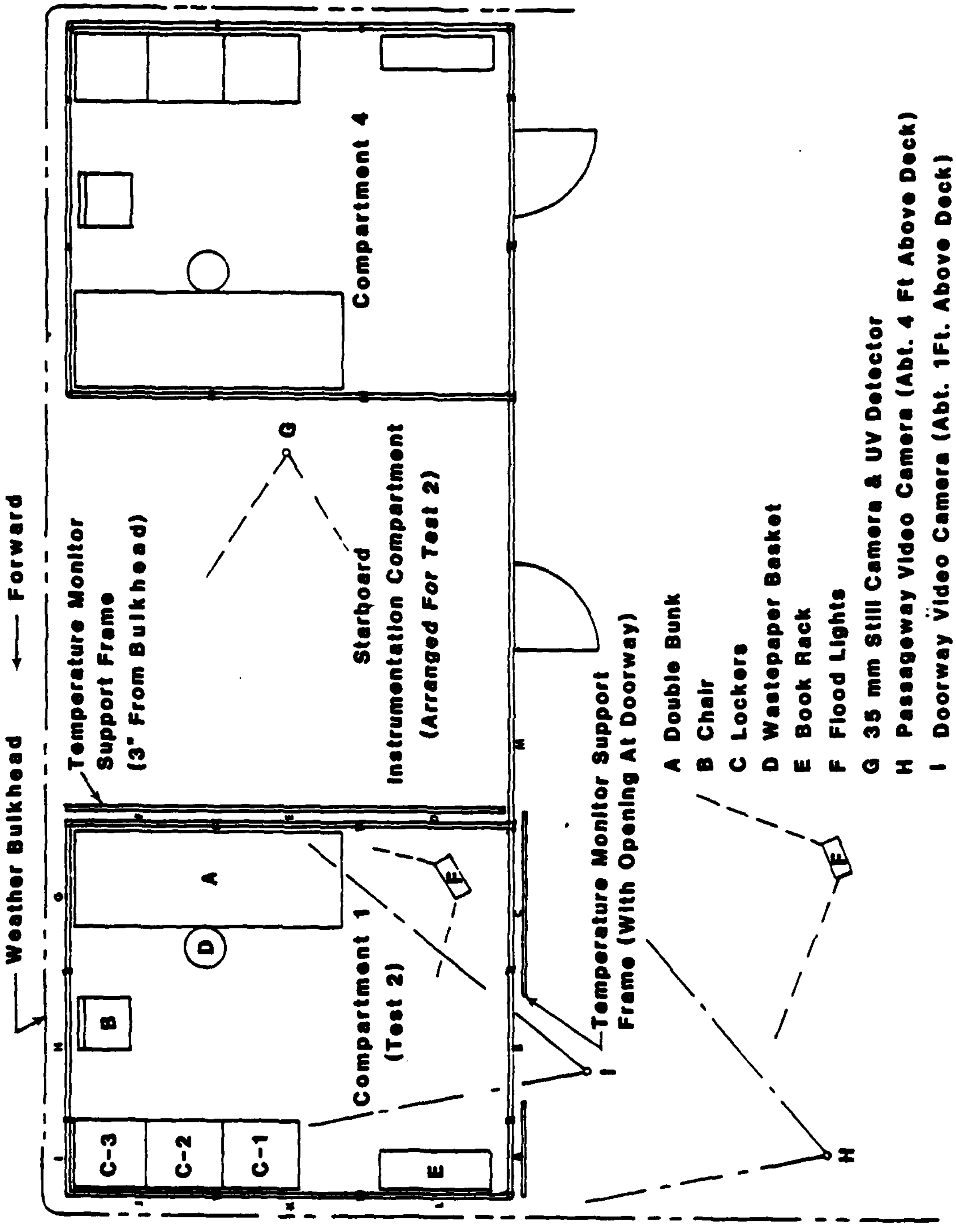
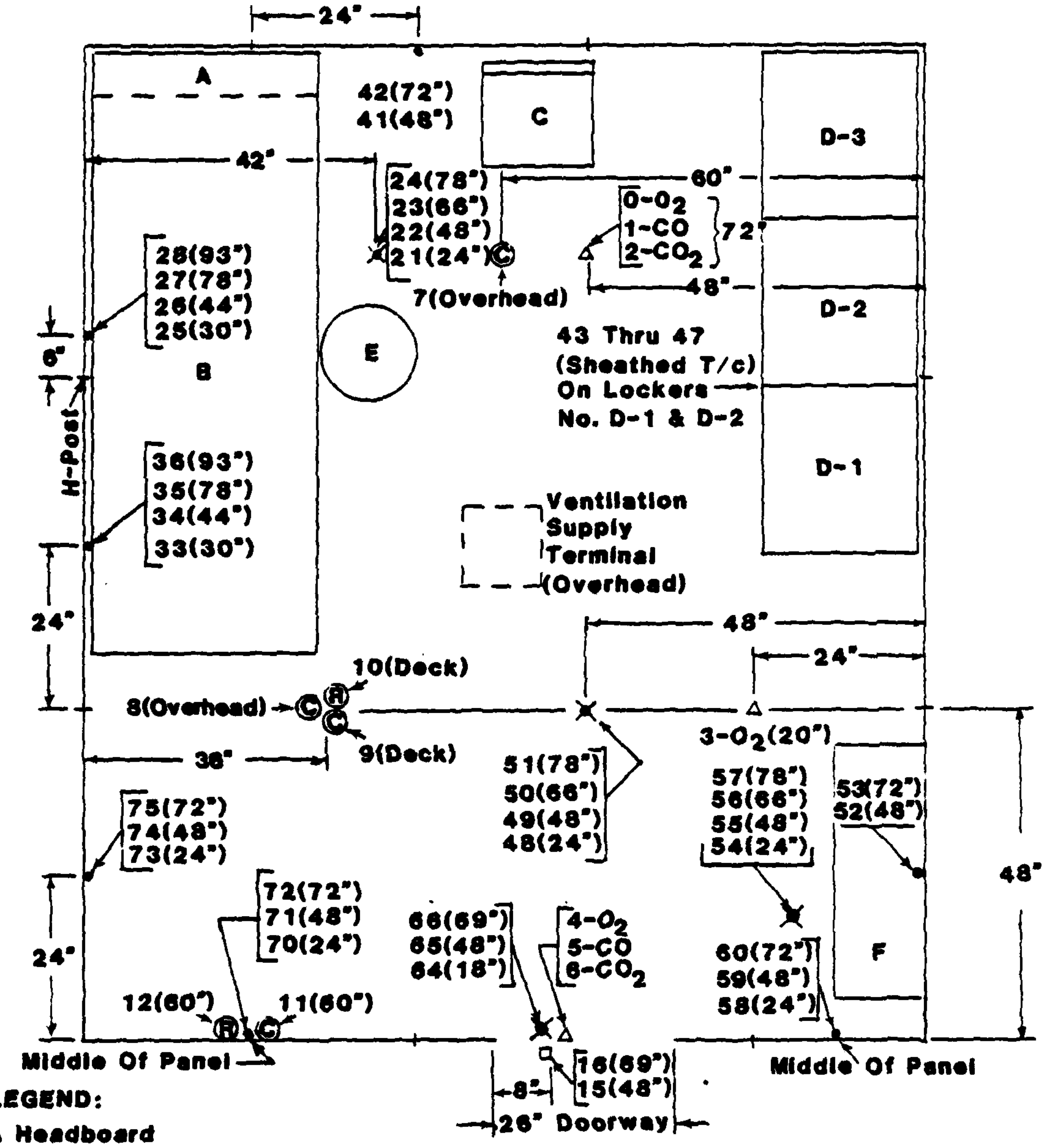


FIGURE 6

CAMERA AND ULTRAVIOLET DETECTOR LOCATIONS



LEGEND:

A Headboard

B Bunks

C Chair

D Locker

E Wastepaper Basket

F Book Rack

● Sheathed Bulkhead-Mounted Thermocouple

✕ Sheathed Thermocouple String

△ Gas Analyzer Probe

Ⓒ Calorimeter

Ⓡ Radiometer

□ Air Flow Probe

51 (78") Channel Number And Height Above Deck

NOTES:

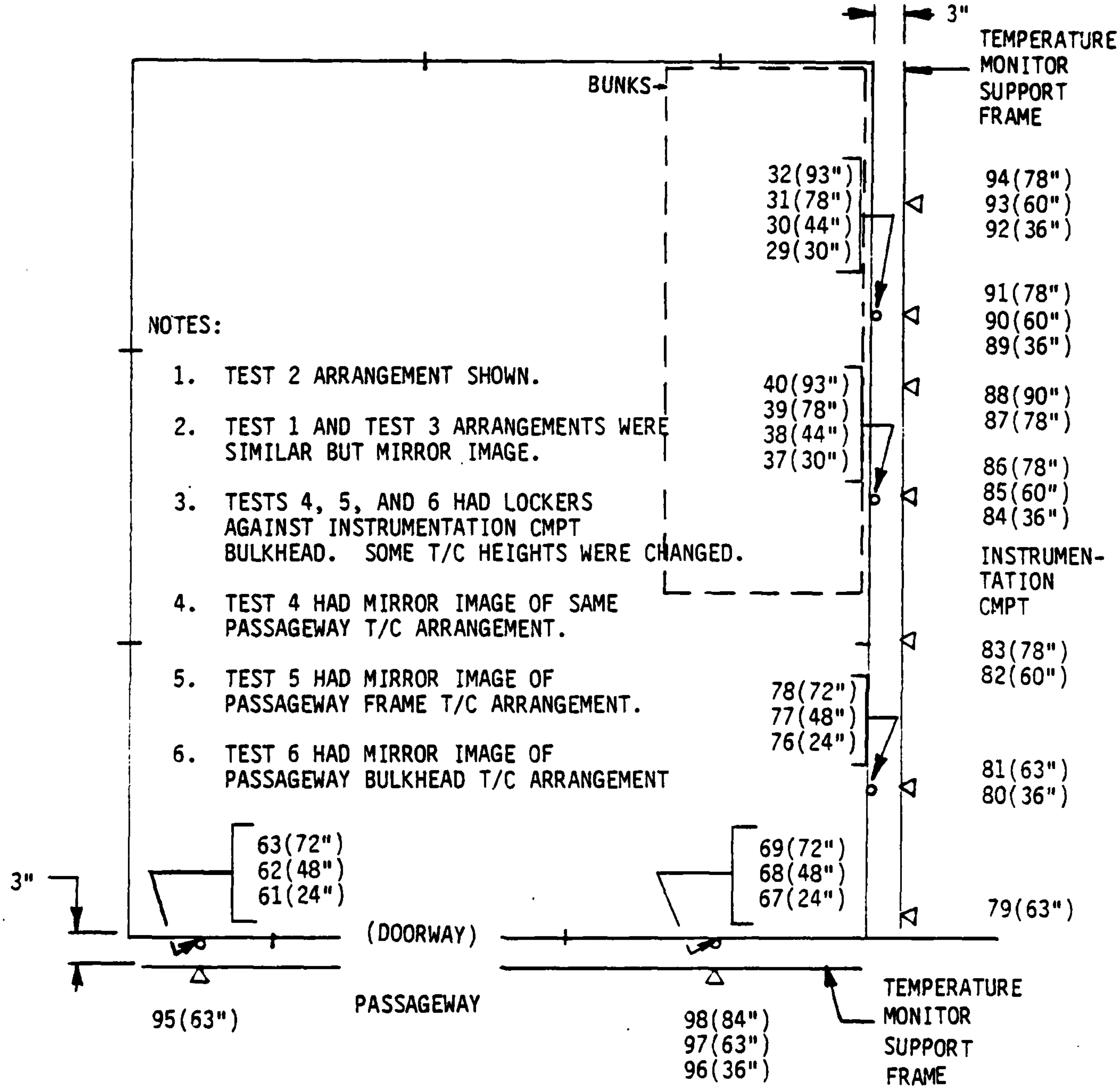
1. Furniture Arrangement Was As Shown For Tests 1, 3, 4 And 6. Arrangement For Tests 2 And 5 Was Mirror Image.
2. Location Of Sensors Relative To Furniture Was Kept The Same For All Tests.

FIGURE 7

INTERIOR SENSOR LOCATIONS

arrangement of sensors inside the test compartments. Figures 8 and 9 show locations of thermocouples and temperature monitors, respectively, on exterior bulkhead surfaces and on the support frames.

Signals from each of the 99 transducers were recorded by the Marine Fire Research Data Acquisition System (Figure 10) located in the instrumentation trailer aboard an LCM moored alongside the test vessel. Data output in engineering units was presented on the computer CRT and could be made available in hard copy form for continuous real-time monitoring of the tests. For this test series, the sampling rate was 60 channels per second. The scan interval was 15 seconds, giving a total of 240 data points per channel during each 60-minute test.



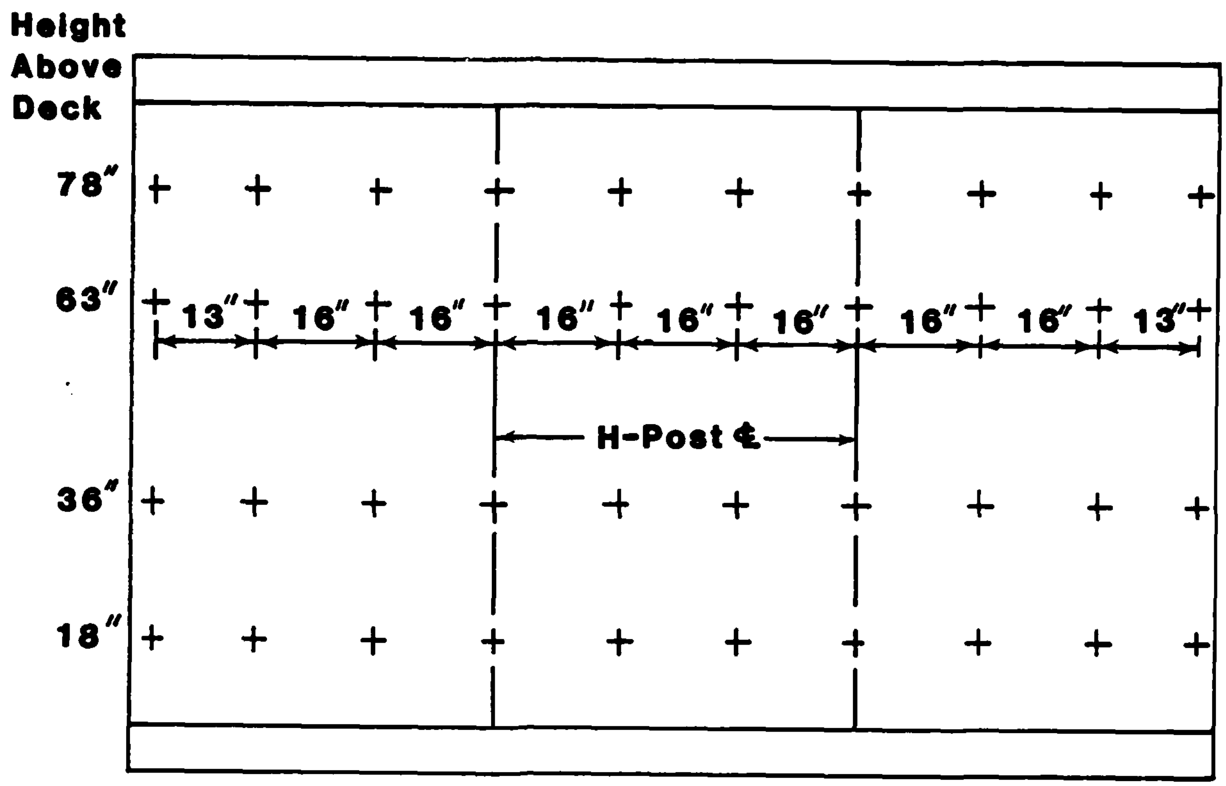
LEGEND

○ BULKHEAD - MOUNTED T/C

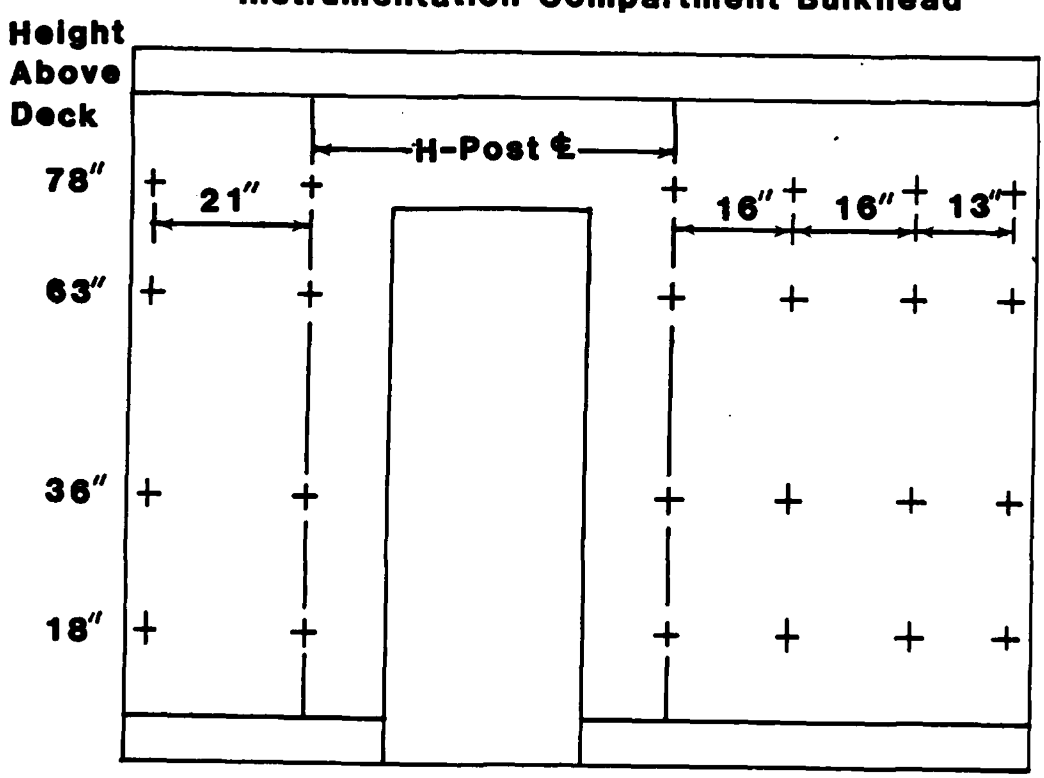
◁ FRAME - MOUNTED T/C

FIGURE 8

EXTERIOR THERMOCOUPLE LOCATIONS



Instrumentation Compartment Bulkhead



Passageway Bulkhead

FIGURE 9

TEMPERATURE MONITOR LOCATIONS

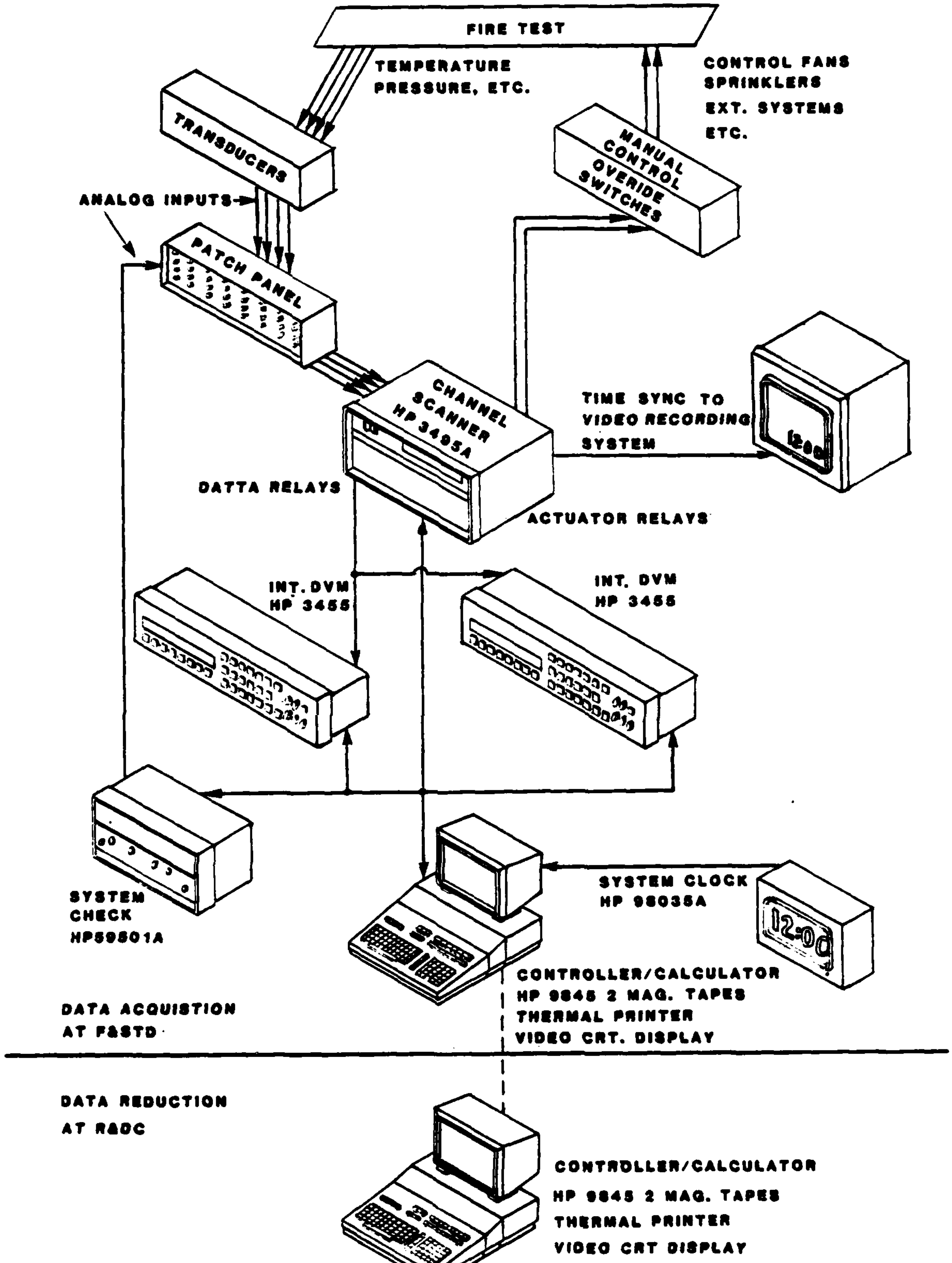


FIGURE 10

MARINE FIRE RESEARCH DATA ACQUISITION SYSTEM

6.0 OBSERVATIONS

6.1 Conditions Observed During Tests

While there was a considerable variation in timing from one test to the next, the sequence given in Table 4 is representative:

TABLE 4

TYPICAL FIRE SEQUENCE

Time After Ignition (Range for Tests 1-6 in parentheses)	Event
30 Seconds (14-60)	Lower bunk bedding ignites
90 Seconds (50-155)	Flames reach upper bunk
3 Minutes (1-7)	Fire develops on deck
8 Minutes (6-19)	TV monitor visibility obscured by smoke
15 Minutes (3-31)	Peak temperature reached on interior bulkhead surfaces
20 Minutes (9-41)	Peak temperature reached in lockers
30 Minutes (9-39)	Peak upper gas temperature reached

Figure 11 shows typical growth of a test fire during the first minute after ignition.

All tests succeeded in creating fires involving bunks, clothing storage lockers and bookracks, the major sources of fuel in a berthing compartment fire. At the end of the 60-minute test period, most temperatures inside the compartment were decreasing steadily, but were still in the 200-400°C range.

6.2 Condition of Furniture and Ceiling Panels After Tests

The double bunk unit, lockers, and bookrack were severely damaged during each test, except for Test 1. That test was the only one in which the bunk unit and the bookrack remained relatively intact.

Except for Tests 1 and 4, the upper bunk pan melted and allowed the steel spring assembly to drop onto the lower bunk. In the remaining tests, large portions of the headboard also were destroyed. Most of the paint on the lower bunk was still visible in all cases. In all tests, the tops of the lockers were destroyed. In Tests 1 and 5, about 75 percent of the doors and sides of the three lockers remained standing. In the remaining tests, the lockers were nearly completely destroyed except for the drawer area at the bottom. Bookrack damage increased progressively. In Test 1, the bookrack remained intact, with its paint burned off exposed areas. In following tests, the amount of damage increased, with the most severe amount occurring in Tests 4 and 6. In these the bookrack remained attached to the bulkhead panel, but was tilted forward with the shelves bent downward 6 to 8 inches at the center. In all tests, the rear of the bookrack remained bolted to the bulkhead panel. Figure 12 shows the typical appearance of the furniture after the test fires.

(a) 35 Seconds

(b) 63 Seconds

FIGURE 11

FIRE GROWTH AFTER IGNITION IN TEST 5

(a) Bunks

(b) Lockers

(c) Bookrack

FIGURE 12

TYPICAL CONDITION OF FURNITURE AFTER FIRE

Except in Test 1, almost none of the fiberglass ceiling panels remained in place after the fires. Their thin plastic facing quickly burned off and the combination of warpage and melting of the ceiling support grid and thermal currents was sufficient to dislodge them.

The percentages of the various combustible items that were consumed in the fires are shown in Table 5. These percentages were estimated from a visual examination, since weighing the remains would have given misleading results because of the water absorbed during extinguishment at the end of the tests.

TABLE 5

TEST COMPARTMENT FIRE LOADING

COMBUSTIBLE ITEMS	FUEL WEIGHT PRESENT IN COMPARTMENT	PERCENT CONSUMED RANGE	PERCENT CONSUMED TYPICAL	TYPICAL FIRE LOAD
Mattresses and bedding	78 lb	80-95	90	70 lb
Clothing	160 lb	80-95	85	136 lb
Publications	140 lb	30-40	30	42 lb
Wood	40 lb	95-100	100	40 lb
Miscellaneous	20 lb	80-95	90	18 lb
	438 lb			306 lb

Fire Loading: 306 lb / 120 sq ft = 2.6 lb/sq ft of floor area

6.3 Condition of Bulkhead Panels After Tests

6.3.1 General

All bulkhead panels retained their integrity. There were no signs of any actual or impending burn-throughs. With all types of panels, the honeycomb core was severely charred in most of the areas higher than 1-2 feet above the deck, and crumbled under slight pressure. While this allowed the panel facings to be easily pushed in an inch or more, the panel facings and cores remained together and showed no tendency to fall away from the joiner system even when shoved or kicked with considerable force. In the case of the nonmetal-faced panels, there was no indication of burning away or disintegration of the facing where panel edges had been exposed.

Where breaches occurred in the bulkheads, it appeared that the usual cause was insufficient engagement of the panel in its joiner system. The type of H-post (see Figure 2) used in test compartment construction allows for insertion of the bulkhead panels about 7/8-inch into the space between the parallel flanges of the post, but in some cases the panels were

gripped by as little as 1/8-inch. Once the panels are in place this inadequate engagement cannot easily be detected. During the fires, distortion of the panels and warpage of the joiner system allowed some panels to separate from their posts. Usually the length of this separation along the post extended no more than a foot or so.

In each test compartment, the bookrack was attached directly to bulkhead panel D or L by four bolts projecting through the panel. In all tests, the bulkhead panels retained sufficient local strength to resist tearing out of the bookrack attachment bolts.

6.3.2 Nonmetal-Faced Panels (Tests 1 and 4)

Nonmetal-faced panels tended to bulge noticeably away from the fire. In Test 1, Panel F (closest to the bunks, on the left in Figure 13a) bulged outward so that it nearly touched the instrumentation frame positioned 3 inches away from the panel surface. This panel did not pull free from the joiner system, however. Judging from marks on the panel, its edges moved about 1/2-inch outward from its installed position, but its initial engagement was sufficient to prevent any actual breach. A small breach did occur about halfway up panel D, at a point where initial engagement with the H-post appears to have been about 1/8-inch. The gap was about 6 inches long by 1/4-inch wide. A Tempilabel that was about 4 inches away and directly in line with the breach did not register any temperature indication. There was no soot on the label, and thermocouples in the frame directly above gave no indication of a temperature rise due to a breach. This suggests that the breach occurred at the end of the test, possibly when the fire in the compartment was being extinguished.

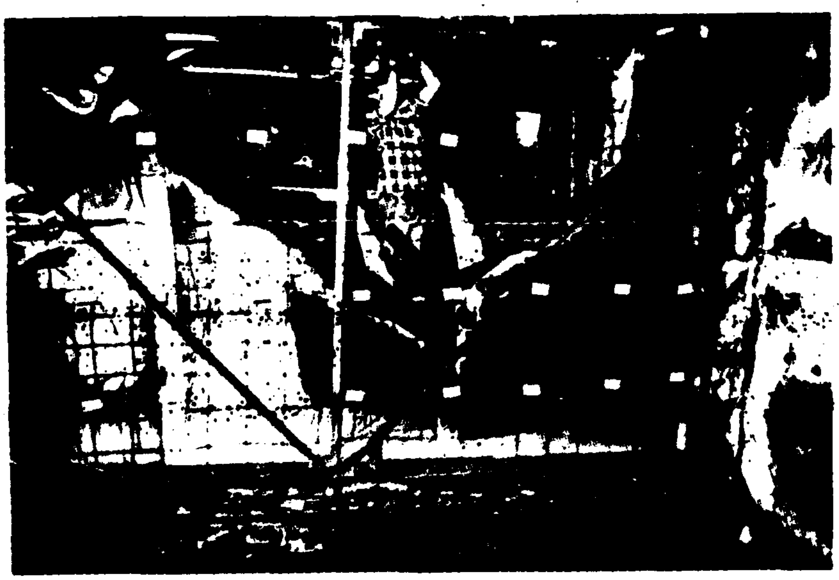
As shown in Figure 13b, large blisters with irregular outlines formed on the panel surfaces facing the fire. These blisters ranged from 6 inches to 2 feet in diameter by 1/2-inch high and were probably caused by outgassing from the core material and adhesives. Facing laminations were separated in the blistered areas.

In Test 4, two fiberglass H-posts were used in the bulkhead facing the instrumentation compartment. The objective was to determine whether a nonmetal joiner system would closely match the thermal expansion of the nonmetal faced panels and reduce the tendency of the panels to separate from the joiner system during a fire. Approximately 35 minutes into the test, this bulkhead gave way and the upper portions of panels E and F folded over into the test compartment. This occurred because of inadequate support of the joiner system. The fiberglass H-posts were not securely attached to the curtain plate and coaming plate. The upper Z-bars also warped in areas where there was a wide spacing between screws attaching them to the curtain plate. As the panels distorted due to heat, they eventually came free of the Z-bar and the weight of the bookrack attached to panel D caused the bulkhead to lean into the test compartment. Panel D remained clamped in corner post C/D/M and prevented complete collapse of the bulkhead. Figure 13c shows the appearance of this bulkhead after the test.

Prior to Tests 1 and 4, it was noted that some of the panels had areas where the core honeycomb cells had little or no foam filling. This

(a) Exterior surface of panels F, E and D after Test 1

(b) Blisters on interior surface of panel H after Test 1



(c) Exterior view of panels D, E and F after Test 4

FIGURE 13

NONMETAL-FACED PANELS AFTER FIRE

condition occurred in isolated cells as well as in irregular 3 to 6-inch diameter patches and in single-cell rows 6 inches to 2 feet long. The affected areas could be seen by holding a flashlight against one side of the panels and observing the opposite side in darkness. The lack of foam filling did not appear to have any effect on the fire performance of the panels; there was no more facing separation, bulging or other deterioration in these areas than there was anywhere else on the panels.

6.3.3 Galvanized Steel-Faced Panels (Tests 2 and 6)

Overall, the steel-faced panels in Tests 2 and 6 showed less tendency to bow away from the fire than did the nonmetal-faced panels. The greatest amount of bowing observed was 1/2 to 3/4-inch. Following the fires, the galvanized coating inside the test compartments was found to be burned off the upper part of the panels, starting about 2 feet above the deck, as shown in Figure 14. The interior steel facing showed much severe wrinkling. Exterior surfaces remained generally wrinkle-free and retained most of their galvanized coating. See Figure 15.

In Test 2, several patches of soot 2 or 3 inches in diameter on exterior surfaces adjacent to H-posts showed that smoke had passed through the bulkheads. The panels were not distorted in these areas and appeared to be tight against the H-posts. A significant breach was observed in Test 2 at H-post E/F (located adjacent to the bunks). Starting at about 30 inches above the deck, the H-post was badly distorted. The H-post and adjacent portions of panels E and F showed a wave-shaped distortion, bending into and out of the test compartment a total of three times between 30 and 60 inches above the deck. Gaps of about 1/2-inch occurred between the H-post flanges and the panel facings. See Figures 15a and 15b.

In all areas, there was a more complete separation of the facing sheets from the core material than was observed with the nonmetal-faced panels. The galvanized steel interior facings tended to bulge into the compartment over much of the upper portions of the panels. These panels however, showed no greater tendency to separate from their tracking system than did the nonmetal-faced panels, even after the panel facings were pushed in and out several times by hand and the charred core material had been largely crushed and separated from the facing sheets.

In Test 6, a large breach occurred along nearly the entire length of the instrumentation compartment bulkhead, at the top of panels D, E, and F. This area is shown in Figure 15c. Prior to the test, it was noted that the curtain plate was somewhat distorted in this area, and that the inboard edge of panel E was not inserted into H-post D/E for a distance of 15 inches down from the top. The curtain plate Z-bar along this bulkhead was welded to the curtain plate at intervals of 15 to 18 inches to improve support conditions for the bulkhead panels in an attempt to compensate for the improper installation. About 30 minutes into the test, the upper portion of the bulkhead began to separate from the curtain plate. The upper ends of H-posts D/E and E/F were pulled free of the curtain plate, and the bulkhead as a unit leaned into the test compartment, creating an irregular breach up to 8 inches wide. The weight of the bookrack attached to panel D helped cause the bulkhead to lean. The upper half of panel D was pulled free from corner post C/D/M.

(a) Bulges and wrinkles on interior panel facings near bunks after Test 2

(b) Wrinkled facing on panel H after Test 2

FIGURE 14

GALVANIZED STEEL-FACED PANELS AFTER FIRE (INTERIOR)

(c) Bowed H-Post L/K after Test 6

FIGURE 14. (Continued)

(a) Panels D, E and F after Test 2

(b) H-Post E/F after Test 2

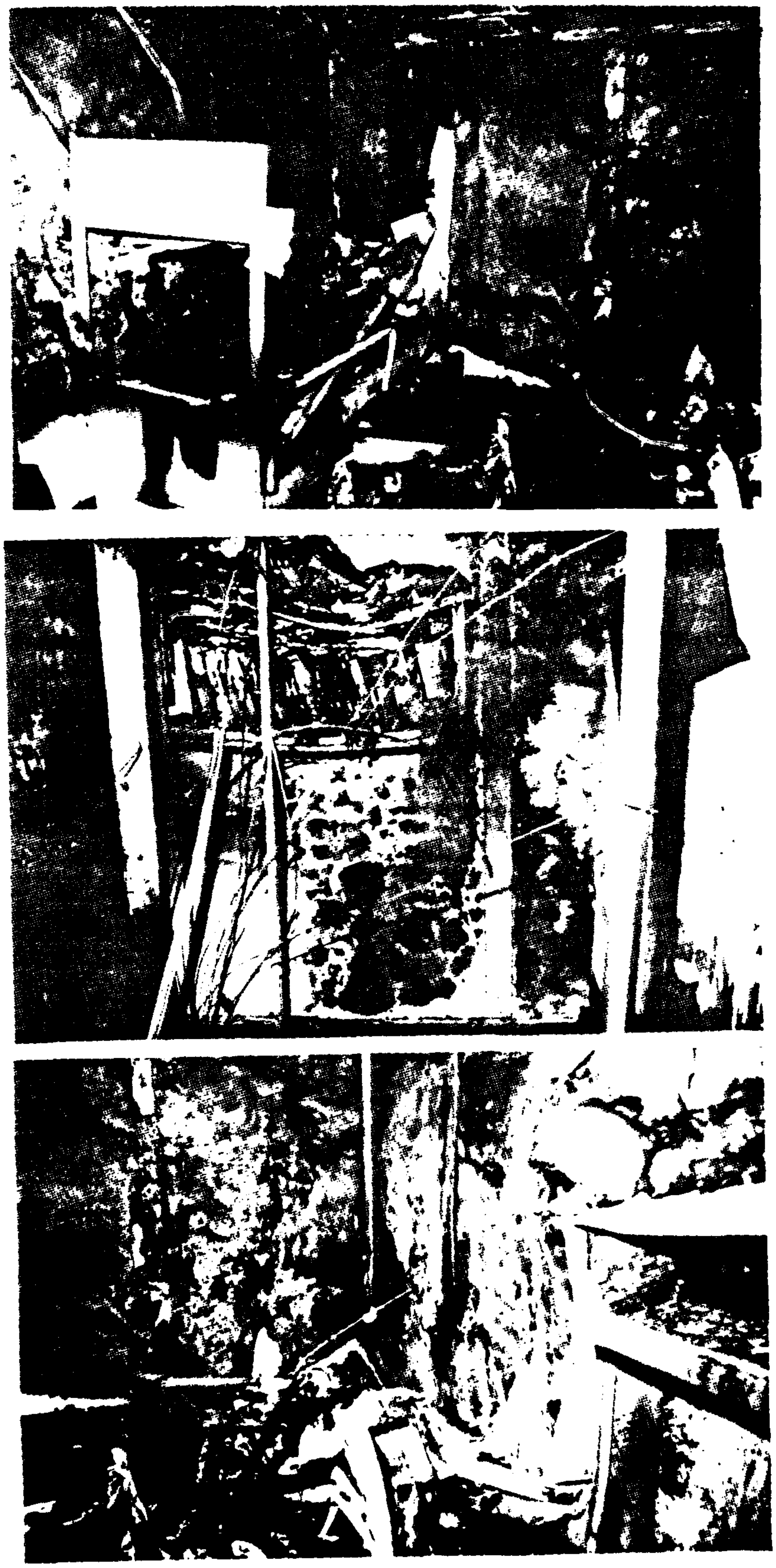
(c) Panels D and E after Test 6

FIGURE 15

GALVANIZED STEEL-FACED PANELS AFTER FIRE (EXTERIOR)

6.3.4 Painted Steel-Faced Panels (Tests 3 and 5)

Compared with the galvanized panels, slightly less wrinkling occurred on the interior facing sheets, which were thicker material on the painted panels. Overall bulging of the panels appeared to be slightly less than was observed with the galvanized panels. See Figure 16. About the same number of small sooted areas on exterior surfaces were noted adjacent to H-posts as in Tests 2 and 6, indicating areas where small amounts of smoke had passed through the bulkhead. No major breach occurred in either test. On interior surfaces, the paint was almost entirely burned off most of the panels. On the instrumentation compartment bulkhead exterior surfaces, paint was burned off a large area opposite the bunks (Test 3; see Figure 17a) or lockers (Test 5). Paint on the passageway bulkhead was burned off the upper 3 feet of the panels, as shown in Figure 17b. The remainder of the paint on both bulkheads was not scorched or blistered.



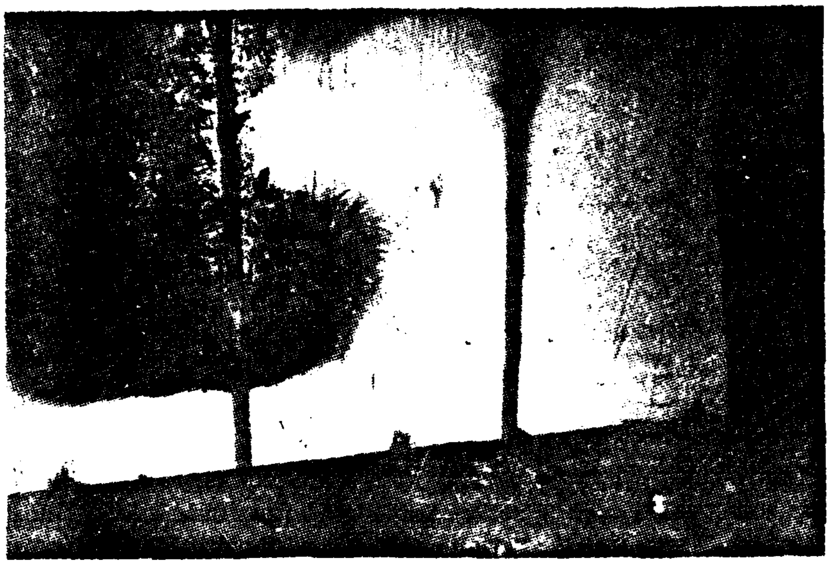
(a) Panels near bunks, showing bowed H-post E/F after Test 3

(b) Wrinkled facing on panel D after Test 5

(c) Bowed H-post J/K after Test 3

FIGURE 16

PAINTED STEEL-FACED PANELS AFTER FIRE (INTERIOR)



(a) Exterior surface of panels F, E and D after Test 3

(b) Exterior surface of panels M and C after Test 3

FIGURE 17

PAINTED STEEL-FACED PANELS AFTER FIRE (EXTERIOR)

7.0 DISCUSSION OF TEST DATA

7.1 General

The severity of a test fire can be measured in several ways, including maximum or average temperatures, rate of initial temperature rise, and number and magnitude of heating/cooling cycles that occur. For this analysis, the following parameters were selected for characterizing fire severity:

Maximum upper gas temperatures inside the test compartment
Area under the upper gas time-temperature curves

7.2 Gas Concentration

Of the three gas analyzer probe locations shown in Figure 6, the one at the rear of the test compartment gives the best indication of conditions resulting from the fire, as it is nearest to the major concentration of fuel. Minimum oxygen concentrations tended to occur at the same time as maximum upper gas temperatures, suggesting that if more oxygen (higher ventilation airflow) had been available, higher upper gas temperatures might have been attained during the fire.

As would be expected, carbon monoxide concentrations generally peaked at the same times that oxygen concentrations reached their minimums, reflecting greater amounts of incomplete combustion due to lack of oxygen. Carbon dioxide concentrations peaked at the same time as temperature. Extreme values of gas concentrations are given in Table 6.

7.3 Heat Flux

Calorimeters (for measurement of total heat flux) and radiometers (for measurement of the radiant portion only) were placed at six locations inside the test compartments. For this test series, their primary purpose was to give indication of any abnormalities in the fires, such as extremely high or low heat flux.

Observed peak values were reasonably consistent although calorimeter failure occurred in area of the bunks and lockers during three of the tests so that comparison between different tests is difficult.

Peak total heat flux in the overhead area ranged between 2.3 and 6.6 watts per sq. cm. At bulkhead panel C, peak values recorded 5 feet above the deck ranged from 1.9 to 6.7 watts per sq. cm. Table 7 shows peak values of heat flux for each test.

7.4 Airflow

The primary reason for measuring doorway airflow in these tests was to provide an additional means of timing any major burnthrough or collapse of a test compartment bulkhead. Normally, thermocouple data would indicate when such a failure occurred, but thermocouples in the area could be disabled by a widespread bulkhead collapse, or by other causes. In the two cases where large breaches occurred, adequate indication of timing was obtained from

TABLE 6

GAS CONCENTRATIONS

	TEST NUMBER 1	2	3	4	5	6
Minimum Oxygen Concentration At:						
Rear of Compartment (CH 0)						
Concentration (%)/Time(Minutes)*	7.5/21	8.6/21	5.0/31	2.3/38	6.5/4	0/17
Middle of Compartment (CH 3)						
Concentration (%)/Time(Minutes)*	17.3/25	15.8/12	16.0/33	15.7/39	14.4/4	14.2/31
Doorway (CH 4)						
Concentration (%)/Time(Minutes)*	12.1/21	10.6/18	8.7/28	6.2/39	7.8/30	4.2/29
Maximum Carbon Monoxide Concentration at:						
Rear of Compartment (CH 1)						
Concentration (%)/Time(Minutes)*	2.0/21	1.6/20	1.8/31	4.3/38	1.3/2	5.3/17
Doorway (CH 5)						
Concentration (%)/Time(Minutes)*	1.4/21	1.5/10	1.5/28	2.5/39	2.0/29	2.0/21
Maximum Carbon Dioxide Concentration at:						
Rear of Compartment (CH 2)						
Concentration (%)/Time(Minutes)*	14.8/21	13.0/21	15.0/31	16.7/38	15.4/4	18.4/17
Doorway (CH 6)						
Concentration (%)/Time(Minutes)*	11.9/5	10.6/18	13.6/27	11.4/39	11.6/30	13.5/29

*Time is measured from test ignition

TABLE 7

MAXIMUM HEAT FLUX
(All heat flux values in watts per square centimeters)

	Test Number 1	2	3	4	5	6
Total Heat Flux						
Overhead, rear of Compartment (CH 7)						
Flux/Time (minutes)*	2.7/5	2.3/20	ND	3.8/38	3.4/3	6.6/30
Overhead, Middle of Compartment (CH 8)						
Flux/Time (Minutes)*	3.7/5	4.0/8	ND	ND	5.5/3	ND
Deck, Middle of Compartment (CH 9)						
Flux/Time (Minutes)*	1.0/5	1.0/8	1.1/30	0.6/9	1.1/3	3.9/7
Bulkhead Panel C (CH 11)						
Flux/Time (Minutes)*	6.7/5	4.3/8	5.9/30	5.0/36	1.9/2	3.4/17
Radiant Heat Flux						
Deck, Middle of Compartment (CH 10)						
Flux/Time (Minutes)*	0.2/5	0.8/8	0.6/30	1.5/9	0.9/3	1.3/7
Bulkhead Panel C (CH 12)						
Flux/Time (Minutes)*	2.7/5	ND	0.9/15	0.4/36	0.7/3	0.7/15

*Time is measured from test ignition

nearby thermocouples, so that airflow data was not needed for this purpose. For this reason, and because only two probes were actually installed for the tests, airflow data is not included in this report.

7.5 Temperatures

Upper gas temperatures provide the most useful means for comparing severity of the six test fires. Figure 18 shows the average of the temperatures measured by channels 24, 51, and 57. All three were 78 inches above the deck and locations relative to the test compartment furniture were as indicated in Figure 7. For comparison, Figure 18 includes the temperature-time curve used to control ASTM E119 tests. Another measure of the fire severity is shown in Figure 19, where the cumulative areas beneath the curves of Figure 18 have been plotted against time.

As might be expected for a relatively small number of tests, the upper gas temperature data shows considerable variation, even though test conditions were made as consistent as possible throughout. Generally, the time-temperature curves have the following characteristics:

- Initially, the temperatures rise rapidly, at a similar rate. This initial rate was very close to that of the ASTM E119 temperature-time curve:

- A peak temperature is attained within 5 to 15 minutes, after which the temperature drops 100°C to 300°C nearly as rapidly as it initially rose. This decrease occurs over 10 to 15 minutes and is probably due to temporary oxygen depletion inside the compartment following rapid initial combustion of fuel.

- 20 to 30 minutes after the start of the fire, as more oxygen is supplied by the ventilation system, renewed burning causes temperatures to rise again. This rise is not as rapid as at the start of the fire, and the second peak temperature is not as high as the first.

- Following the second peak, temperatures decline steadily as the supply of combustible material is exhausted. This second decline is more gradual than that following the initial peak.

Maximum temperatures for each thermocouple location may be found in the following tables:

Gas Temperatures:	Table 8
Locker Temperatures:	Table 9
Interior surface temperature:	Table 10
Exterior surface temperatures:	Table 11
Frame Temperatures (3 inches away from exterior surfaces):	Table 12

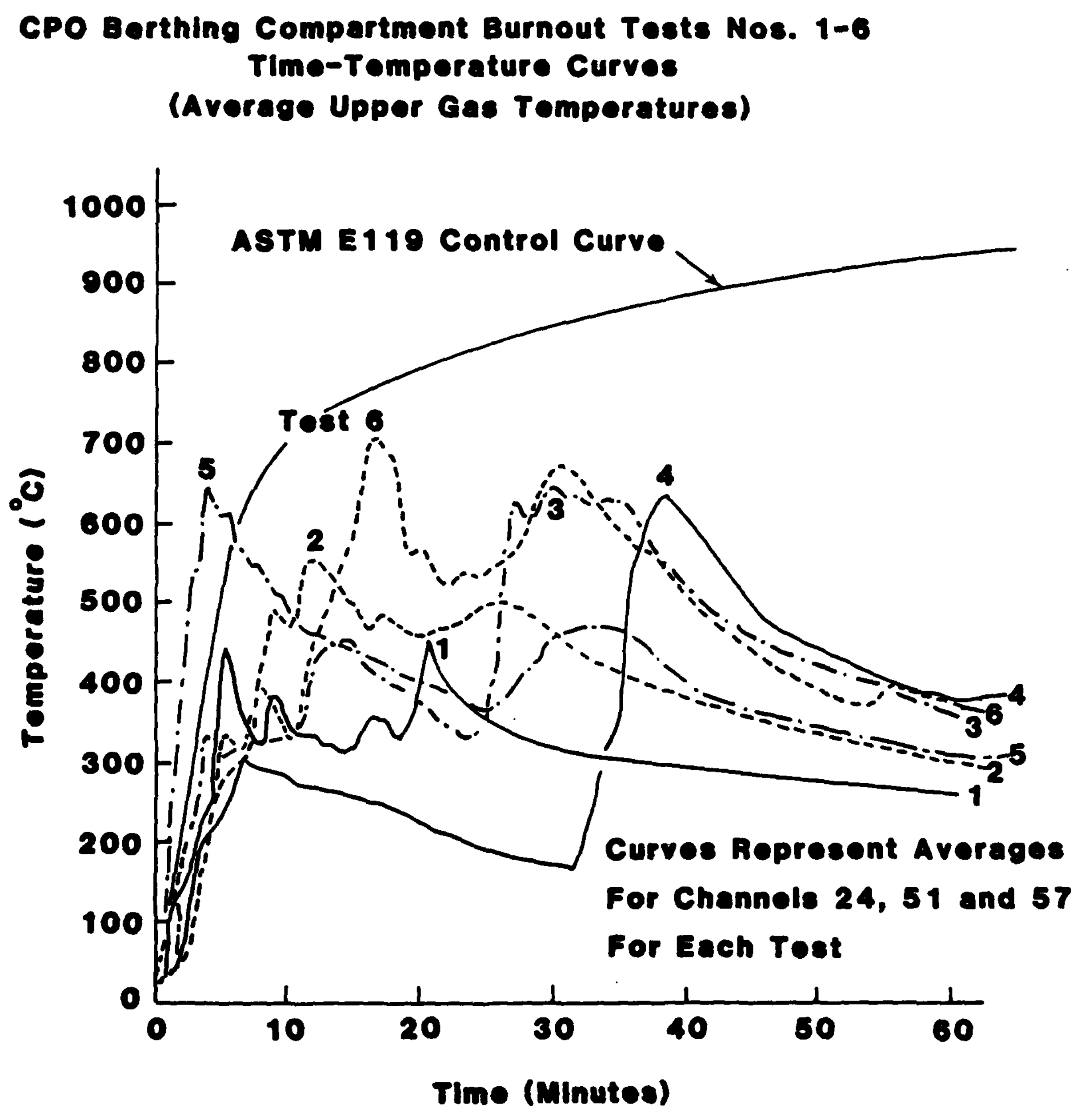


FIGURE 18

AVERAGE UPPER GAS TEMPERATURES

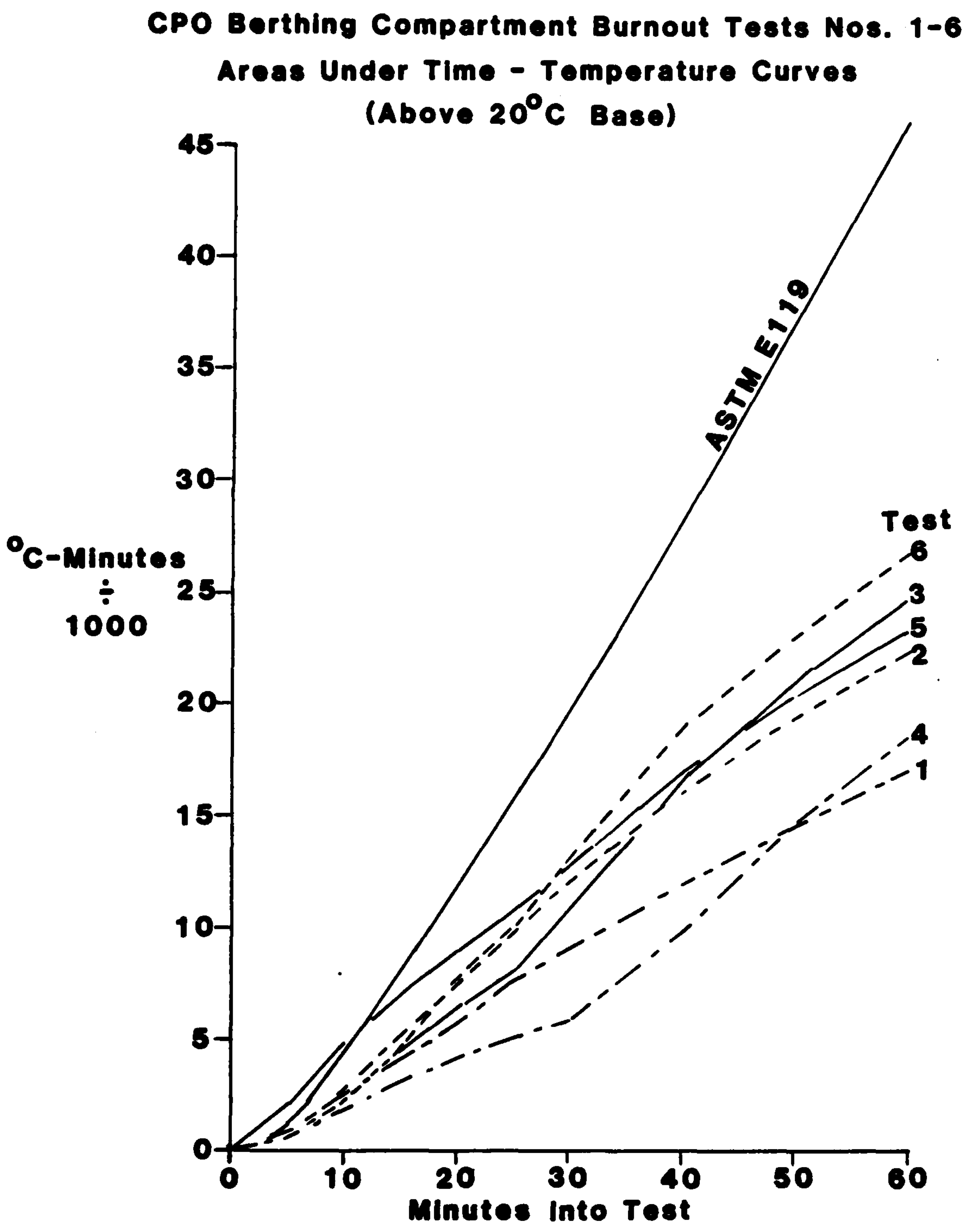


FIGURE 19

CUMULATIVE TIME-TEMPERATURE CURVES

TABLE 8

MAXIMUM GAS TEMPERATURES
(All Temperatures in ^{o}C)

LOCATION (Height above deck shown in parentheses)		TEST NUMBER 1	2	3	4	5	6
Rear of Compartment							
(24")	CH 21	381	443	445	421	348	623
(48")	CH 22	378	612	545	455	702	692
(66")	CH 23	465	581	629	595	567	784
(78")	CH 24	597	630	641	610	607	783
Middle of Compartment							
(24")	CH 48	ND	ND	ND	ND	ND	ND
(48")	CH 49	325	394	530	ND	391	636
(66")	CH 50	394	436	628	609	488	686
(78")	CH 51	ND	513	661	651	635	771
Near Bookrack							
(24")	CH 54	188	271	349	429	ND	489
(48")	CH 55	386	352	480	526	436	563
(60")	CH 56	484	602	687	636	563	717
(78")	CH 57	529	659	693	666	725	720
Doorway							
(18")	CH 64	54	63	90	90	83	170
(48")	CH 65	241	315	446	362	349	499
(69")	CH 66	418	418	578	492	561	592

ND=No data obtained

TABLE 9

MAXIMUM LOCKER TEMPERATURES
(All Temperatures in ^{o}C)

LOCATION	TEST NUMBER 1	2	3
TESTS 1 - 3			
Locker No. 1			
inside drawer (CH 43)	696	510	368
inside door, near center, 6 inches from top (CH 44)	783	801	591
inside door, near center, halfway down (CH 45)	508	660	798
same as CH 44 but on outside surface (CH 46)	461	878	568
Locker No. 2			
same as CH 45 (CH 47)	818	677	912
TESTS 4 - 6	4	5	6
Locker No. 1			
inside drawer (CH 43)	377	90	427
inside door, above bar (CH 44)	657	643	707
inside door, 6 inches below bar (CH 45)	459	ND	ND
Inside door, on bottom (CH 46)	561	182	450
Locker No. 2			
same as CH 45 (CH 47)	833	470	832

ND=No data obtained

TABLE 10

MAXIMUM INTERIOR SURFACE TEMPERATURES
(All Temperatures in ^{o}C)

LOCATION (Height above deck shown in parentheses)	TEST NUMBER 1	2	3	4	5	6
Near Middle of Bunks (Panel F or J)*						
(30") CH 25	462	875	965	380	841	523
(44") CH 26	601	899	965	496	897	798
(78") CH 27	553	782	ND	668	901	787
(93") CH 28	181	ND	785	475	775	768
Near Foot of Bunks (Panel E or K)*						
(30") CH 33	488	717	720	382	679	780
(44") CH 34	449	824	823	ND	739	815
(78") CH 35	470	632	588	640	727	872
(93") CH 36	185	358	469	588	669	885
Rear of Compartment (Panel H)*						
(48") CH 41	386	609	553	614	368	667
(72") CH 42	546	571	651	657	521	715
Near Bookrack (Panel L or D)*						
(48") CH 52	ND	ND	320	754	331	520
(72") CH 53	440	716	622	603	629	686
Near Bookrack (Panel A or C)*						
(24") CH 58	170	241	ND	388	292	561
(48") CH 59	ND	157	244	240	199	ND
(72") CH 60	163	252	393	327	247	941
Passageway Bulkhead (Panel C or A)*						
(24") CH 70	449	607	652	677	562	662
(48") CH 71	285	384	525	413	381	643
(72") CH 72	363	505	574	406	479	660
Instrumentation Compartment Bulkhead (Panel D or L)*						
(24") CH 73	ND	ND	ND	ND	ND	ND
(48") CH 74	279	365	526	412	392	575
(72") CH 75	394	531	538	448	547	692

*First panel letter is for Tests 1 - 3, second letter is for Tests 4 - 6.
ND=No Data Obtained

TABLE 11

MAXIMUM EXTERIOR SURFACE TEMPERATURES
(All Temperatures in °C)

LOCATION (Height above deck shown in parentheses)	TEST NUMBER 1	2	3	4	5	6
Near Middle of Bunks (Panel F), Tests 1-3						
(30") CH 29	58	136	132	-	-	-
(44") CH 30	77	255	153[a]	-	-	-
(78") CH 31	146	246	164[b]	-	-	-
(93") CH 32	90	526	282[c]	-	-	-
Near Middle of Lockers (Panel F), Tests 4-6						
(24") CH 29	-	-	-	557[a]	76	114
(48") CH 30	-	-	-	222[b]	123	191
(60") CH 31	-	-	-	245	123	202
(78") CH 32	-	-	-	657	167	236
Near Foot of Bunks (Panel E), Tests 1-3						
(30") CH 37	60	143	77	-	-	-
(44") CH 38	51	180	177	-	-	-
(78") CH 39	77	115	139	-	-	-
(93") CH 40	85	99	217	-	-	-
Behind Locker No. 1 (Panel E), Tests 4-6						
(36") CH 37	-	-	-	225	124	144
(48") CH 38	-	-	-	196	92	180
(60") CH 39	-	-	-	241	172	194
(78") CH 40	-	-	-	475	164	213
Near Bookrack (Panel A or C)*						
(24") CH 61	ND	87	118	102	ND	113
(48") CH 62	90	90	231	117	101	131
(72") CH 63	ND	268	321	212	273	304
Passageway Bulkhead (Panel C or A)*						
(24") CH 67	ND	90	91	105	91	ND
(48") CH 68	ND	ND	158	825	141	115
(72") CH 69	169	216	345	816	240	324
Instrumentation Compartment Bulkhead (Panel D or L)*						
(24") CH 76	ND	54	113	178	65	116
(48") CH 77	55	109	125	171	93	168
(72") CH 78	77	95	176	259	115	473

*First panel letter is for Tests 1-3, second letter is for Tests 4-6
ND=No Data Obtained
Changes in Height: a - 36" above deck
b - 48" above deck
c - 66" above deck

TABLE 12

MAXIMUM FRAME TEMPERATURES
(All Temperatures in ^{o}C)

LOCATION (Heights above deck given in parentheses)	TEST NUMBER 1	2	3	4	5	6
Opposite Panel D						
(60") CH 79	52[a]	77	123	184	95	184
(60") CH 80	40[a]	61[a]	98	194	92	224
(78") CH 81	51[b]	77[b]	123	362	107	463
Opposite H-Post D/E						
(60") CH 82	63	78	123	183	98	194
(78") CH 83	60	99	143	389	116	393
Opposite Panel E						
(36") CH 84	40	62	108	134	85	156
(60") CH 85	57	78	123	184	109	186
(78") CH 86	58	91	132	487	165	231
(60") CH 87	63[c]	132	144	192	100	189
(78") CH 88	64[d]	187	196	509	110	216
Opposite Panel F						
(36") CH 89	69	121	143	219	73	171
(60") CH 90	58	129	129	209	97	194
(78") CH 91	62	215	141	538	117	227
(36") CH 92	46	81	118	179	83	168
(60") CH 93	58	90	128	208	130	195
(78") CH 94	60	118	141	230	133	236
Opposite Panel A or C*						
(72") CH 95	170[b]	200[b]	302[b]	240	239	305
Opposite Panel C or A*						
(24") CH 96	63[a]	56[a]	93[a]	90	62	79
(48") CH 97	129[b]	158[b]	277[b]	135	87	94
(72") CH 98	212[e]	240[e]	331[e]	249	242	265

*First panel letter is for Tests 1-3, second letter is for Tests 4-6

Changes in Height: a - 36" above deck
b - 60" above deck
c - 78" above deck
d - 90" above deck
e - 84" above deck

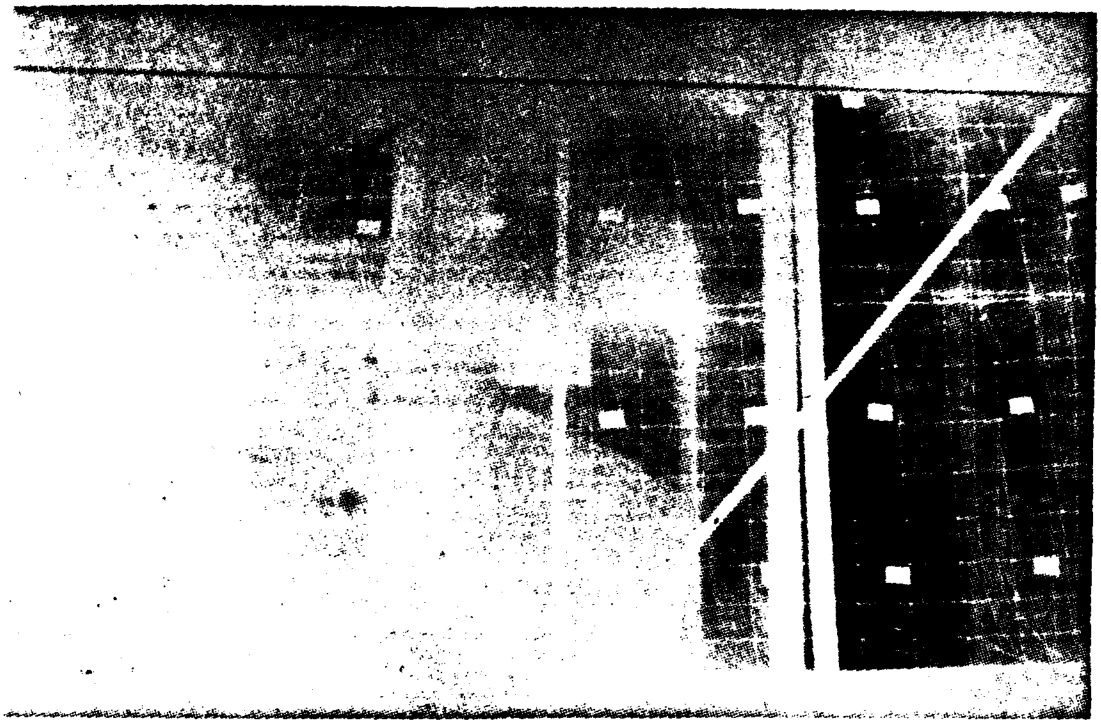
The Tempilabel monitor indicators did not approach 350°F anywhere along the instrumentation compartment bulkhead except in the immediate vicinity of the breaches. Most of the monitors in the top two rows near the passageway bulkhead (60 and 78 inches above the deck) changed color in each test, due to the hot gases flowing out of the open test compartment doorway.

7.6 Ultraviolet Detector

No indication was recorded by the ultraviolet sensor at any time during the tests, indicating that no flames passed through any of the breaches in the instrumentation compartment bulkheads. The two major breaches (Tests 4 and 6) were located at the top of the bulkhead and occurred well into the test, when the flames had probably subsided somewhat. The thick smoke which would have poured into the instrumentation compartment at the time of the breach, as well as the low position of the sensor, would tend to prevent the UV detector from registering the presence of flames within the test compartment.

7.7 Infrared Camera

Infrared photographs (see Figure 20) taken during Test 1 show the shadows of the bunks and the sheathed thermocouple wires on the inside of the test compartment bulkhead. They do not indicate development of any hot spots on the bulkhead itself. The camera malfunctioned during Test 4, and only about 12 frames were exposed. The film is similar to that obtained in Test 1, with shadows of the bookrack and lockers visible, but with no evidence of hot spots. The film exposed during Tests 2 and 6 shows no images at any point. The infrared camera malfunctioned at the start of Tests 3 and 5; the film jammed in the magazine and although the advance continued to operate, no film was exposed.



View of exterior surface of panels F, E and D taken during Test 1

FIGURE 20

INFRARED PHOTOGRAPH

8.0 CONCLUSIONS AND RECOMMENDATIONS

All three panel designs showed good resistance to the test fire conditions, which were representative of the type and severity of fires that could be expected in shipboard berthing areas. No burn-throughs or incipient breakdowns of panel integrity were observed. In the two cases where major breaches occurred in the bulkheads, (see sections 6.3.2 and 6.3.3), the primary cause was poor workmanship during panel installation rather than lack of fire resistance of the panels themselves. Even these improperly installed panels contained the fire for 30 minutes or more before allowing a breach to develop.

Although panel cores were typically almost completely charred, where the panels had been properly installed in the tracking system they were still held securely in place after the fire.

The panels successfully supported the weight of the loaded bookrack during the fire. The panel facings held the bookrack fasteners without allowing pullout.

The 350°F temperature limit was not reached with any of the panel types, except near the compartment doorway and in areas adjacent to the major breaches.

As was demonstrated in these tests, a set of bulkhead panels may be highly resistant to fire, but if their joiner system is improperly designed or installed, they will not provide a satisfactory fire barrier. It is therefore important to consider the panels and joiner hardware as a complete system, and to take whatever steps are necessary to insure that proper installation is accomplished. Close spacing of Z-bar fasteners and secure attachment of the fixed H-post members are means of achieving this. Due to the configuration of the H-posts, it is difficult to detect improper panel engagement by visual inspection once installation is complete. One way of checking for proper engagement would be to measure the width of each panel that is exposed between the flanges of adjacent H-posts. In any case, a minimum panel insertion of 3/4-inch should be insured.

APPENDIX A

FURNITURE

Item (Total Quantity)	Description	Drawing No.
1. Bunks (6)	CPO double bunk unit Aluminum construction	CG FL-3306-25 SH 15
2. Lockers (16)	CPO wardrobe-locker unit Aluminum construction 72"H x 24"W x 22"D	NAVSHIPS 1622093
3. Lockers (2)*	Navy Type B-2 lockers Aluminum construction 72"H x 18"W x 20"D	NAVSHIPS 805-1626432
4. Bookracks (6)	Bulkhead-mounted Aluminum construction 37"W x 25-1/2"H x 12-5/16"D	NAVSHIPS 1749061, Type B
5. Wastepaper Basket (6)	Steel, 13" dia. x 14-1/2"H	FSN 7520-00-281-5911
6. Chair (6)	Steel, straight-back type	

*Used in tests 5 and 6 in locker position No. 3.

APPENDIX B

BEDDING ITEMS

Item (Quantity per compartment)	Description	Federal Stock No.
1. Mattress (2)	Neoprene Foam 76" x 24" x 4-1/2"	7210-00-889-3733
2. Mattress Cover (2)	36" x 88"	7210-00-171-1091
3. Sheet (4)	Cotton-Polyester 90" x 54"	7210-00-482-7072
4. Bedspread (2)	Cotton, 56" x 88"	7210-00-408-2800
5. Pillows (2)	Feather	7210-01-015-5190
6. Pillowcases (2)	Cotton-Polyester 20-1/2" x 30-1/2	7210-00-231-2373
7. Blanket (2)	Wool, 60" x 84"	7210-00-082-5668
8. Bath towel (4)	Cotton, 20" x 40"	7210-00-128-8929
9. Hand towel (2)	Cotton, 17" x 36"	7210-00-243-1019

APPENDIX C

DATA CHANNEL LIST

CHANNEL NO.	DESCRIPTIVE TITLE AND LOCATION (See note)
0	O_2 Concentration, Near Bunks
1	CO Concentration, Near Bunks
2	CO_2 Concentration, Near Bunks
3	O_2 Concentration, 4 Feet From Doorway
4	O_2 Concentration, Doorway
5	CO Concentration, Doorway
6	CO_2 Concentration, Doorway
7	Calorimeter, Ceiling, Near Bunks
8	Calorimeter, Ceiling, Middle of Compartment
9	Calorimeter, Deck, Middle of Compartment
10	Radiometer, Deck, Middle of Compartment
11	Calorimeter, Bulkhead, Panel C
12	Radiometer, Bulkhead, Panel C
13	Air Flow Probe, Ventilation Supply Duct
14	Air Flow Probe, Doorway, 18" Above Deck
15	Air Flow Probe, Doorway, 48" Above Deck
16	Air Flow Probe, Doorway, 69" Above Deck
17	U/V Flame Detector, Instrumentation Compartment
18	Type K Thermocouple Reference Junction, at Patch Panel
19	Thermocouple, Trailer Ambient
20	Thermocouple, Ventilation Supply Duct
21	String T/C, Inside, Near Bunk, 24" Above Deck
22	String T/C, Inside, Near Bunk, 48" Above Deck
23	String T/C, Inside, Near Bunk, 66" Above Deck

CHANNEL NO.	DESCRIPTIVE TITLE AND LOCATION (See Note)
24	String T/C, Inside, Near Bunk, 78" Above Deck
25	Bulkhead T/C, Inside, Panel F, 6" Above Lower Bunk
26	Bulkhead T/C, Inside, Panel F, 6" Below Upper Bunk
27	Bulkhead T/C, Inside, Panel F, 78" Above Deck
28	Bulkhead T/C, Inside, Panel F, 93" Above Deck
29	Bulkhead T/C, Outside, Panel F, 6" Above Lower Bunk
30	Bulkhead T/C, Outside, Panel F, 6" Below Upper Bunk
31	Bulkhead T/C, Outside, Panel F, 78" Above Deck
32	Bulkhead T/C, Outside, Panel F, 93" Above Deck
33	Bulkhead T/C, Inside, Panel E, 6" Above Lower Bunk
34	Bulkhead T/C, Inside, Panel E, 6" Below Upper Bunk
35	Bulkhead T/C, Inside, Panel E, 78" Above Deck
36	Bulkhead T/C, Inside, Panel E, 93" Above Deck
37	Bulkhead T/C, Outside, Panel E, 6" Above Lower Bunk
38	Bulkhead T/C, Outside, Panel E, 6" Below Upper Bunk
39	Bulkhead T/C, Outside, Panel E, 78" Above Deck
40	Bulkhead T/C, Outside, Panel E, 93" Above Deck
41	Bulkhead T/C, Inside, Panel H, 48" Above Deck
42	Bulkhead T/C, Inside, Panel H, 72" Above Deck
43	Thermocouple, Locker No. 1
44	Thermocouple, Locker No. 1
45	Thermocouple, Locker No. 1
46	Thermocouple, Locker No. 1
47	Thermocouple, Locker No. 2
48	String T/C, Inside, Middle of Compartment, 24" Above Deck
49	String T/C, Inside, Middle of Compartment, 48" Above Deck

CHANNEL NO.	DESCRIPTIVE TITLE AND LOCATION (See note)
50	String T/C, Inside, Middle of Compartment, 66" Above Deck
51	String T/C, Inside, Middle of Compartment, 78" Above Deck
52	Bulkhead T/C, Inside, Panel L, 48" Above Deck
53	Bulkhead T/C, Inside, Panel L, 72" Above Deck
54	String T/C, Inside, Near Bookrack, 24" Above Deck
55	String T/C, Inside, Near Bookrack, 48" Above Deck
56	String T/C, Inside, Near Bookrack, 66" Above Deck
57	String T/C, Inside, Near Bookrack, 78" Above Deck
58	Bulkhead T/C, Inside, Panel A, 24" Above Deck
59	Bulkhead T/C, Inside, Panel A, 48" Above Deck
60	Bulkhead T/C, Inside, Panel A, 72" Above Deck
61	Bulkhead T/C, Outside, Panel A, 24" Above Deck
62	Bulkhead T/C, Outside, Panel A, 48" Above Deck
63	Bulkhead T/C, Outside, Panel A, 72" Above Deck
64	String T/C, in Doorway, 18" Above Deck
65	String T/C, in Doorway, 48" Above Deck
66	String T/C, in Doorway, 69" Above Deck
67	Bulkhead T/C, Outside, Panel C, 24" Above Deck
68	Bulkhead T/C, Outside, Panel C, 48" Abvove Deck
69	Bulkhead T/C, Outside, Panel C, 72" Above Deck
70	Bulkhead T/C, Inside, Panel C, 24" Above Deck
71	Bulkhead T/C, Inside, Panel C, 48" Above Deck
72	Bulkhead T/C, Inside, Panel C, 72" Above Deck
73	Bulkhead T/C, Inside, Panel D, 24" Above Deck
74	Bulkhead T/C, Inside, Panel D, 48" Above Deck

CHANNEL NO.	DESCRIPTIVE TITLE AND LOCATION (See note)
75	Bulkhead T/C, Inside, Panel D, 72" Above Deck
76	Bulkhead T/C, Outside, Panel D, 24" Above Deck
77	Bulkhead T/C, Outside, Panel D, 48" Above Deck
78	Bulkhead T/C, Outside, Panel D, 72" Above Deck
79	Frame T/C, Opposite Panel D, 61" Above Deck
80	Frame T/C, Opposite Panel D, 36" Above Deck
81	Frame T/C, Opposite Panel D, 63" Above Deck
82	Frame T/C, Opposite H-Post D/E, 61" Above Deck
83	Frame T/C, Opposite H-Post D/E, 76" Above Deck
84	Frame T/C, Opposite Panel E, 36" Above Deck
85	Frame T/C, Opposite Panel E, 63" Above Deck
86	Frame T/C, Opposite Panel E, 78" Above Deck
87	Frame T/C, Opposite Panel E, 78" Above Deck
88	Frame T/C, Opposite Panel E, 90" Above Deck
89	Frame T/C, Opposite Panel F, 36" Above Deck
90	Frame T/C, Opposite Panel F, 63" Above Deck
91	Frame T/C, Opposite Panel F, 78" Above Deck
92	Frame T/C, Outside, Panel F, 36" Above Deck
93	Frame T/C, Opposite Panel F, 63" Above Deck
94	Frame T/C, Opposite Panel F, 78" Above Deck
95	Frame T/C, Opposite Panel A, 63" Above Deck
96	Frame T/C, Opposite Panel C, 36" Above Deck
97	Frame T/C, Opposite Panel C, 63" Above Deck
98	Frame T/C, Opposite Panel C, 84" Above Deck

Note: As indicated in Tables 8, 11 and 12, some thermocouple heights were changed between tests.